Pleistocene Geology of the St. Lawrence Lowland

BY

Paul MacClintock and David P. Stewart

NEW YORK STATE MUSEUM
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BULLETIN NUMBER 394

The University of the State of New York
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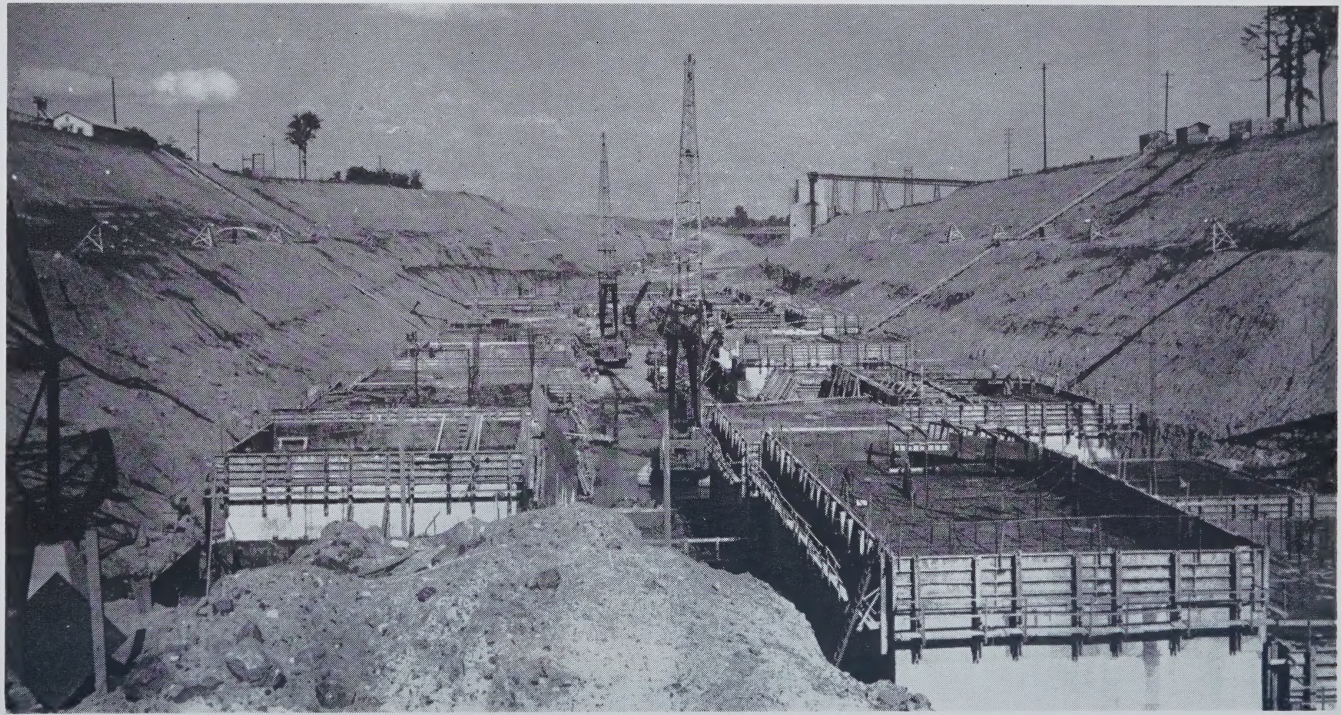

FRONTISPIECE. Eisenhower lock excavation. Lower and Middle (Malone) tills and upper till (Fort Covington) distinguished by ground water seepage in sides of cut.

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CHAPTER I

Introduction

Location

The St. Lawrence Lowland comprises that part of New York State northward from the Adirondack upland and the Tug Hill Plateau to the St. Lawrence River, and from Lake Ontario eastward to the international boundary north of Malone, roughly 25 by 120 miles, or approximately 3,000 square miles in area.

This is gently rolling country, below 1,000 feet in altitude and with only 100 to 200 feet of local relief. It is a well-populated agricultural area specializing in dairy products. The small cities from west to east are Watertown, Gouverneur, Ogdensburg, Canton, Potsdam, Massena, Malone, and Chateaugay. The area is traversed by branches of the New York Central and the Rutland Railroads. It is also crossed by many excellent roads—major U. S. highways, as well as State, county, and township roads—so that all parts are easily reached by car. The lowland is entirely mapped on inch-to-a-mile (1:62,500) U. S. Survey topographic maps (figure 1), many of which, marked by a triangle on the index map, have been resurveyed (on larger scale, 1:24,000 and 1:31,680). These are available from the U. S. Geological Survey, and also at several stationery stores in the area.

Field Procedure

This report is based on five seasons of field study by MacClintock and three by Stewart. The mapping was done by systematic road traverse, examination of all exposures, and frequent auger borings, all plotted directly on the 1:24,000 and 1:31,680 topographic maps where these were available. These data have been transferred to 1:62,500 maps for ease of compilation of the present maps.

Map Symbols

The maps show the distribution of surficial material lying on the bedrock. Map symbols were chosen to show the distribution of materials deemed significant to agriculture, engineering, ground water, and structural material supplies such as sand, gravel, and clay. Also, the units mapped are those significant to the geologic history of the region.

1. Till is mapped in four phases: (1) Till in a sheet showing little or no morainal topography; (2) frontal moraine with rough hummocky topography, formed at the margin of the glacier; (3) ground moraine with broad gentle swell-and-swale topography deposited beneath the glacier and/or overridden by the ice; (4) till covered with a thin deposit of silt and clay.
2. Gravel is mapped in four phases: (1) Kame and kame terrace gravel is the coarse gravel containing cobbles and boulders deposited by meltwater at the edge of the ice; (2) winnowed till is the gravel left when waves of the lakes or Champlain Sea "winnowed" out the clay, silt, and fine sand of the till to leave coarse, poorly rounded gravel; (3) beach gravel was deposited in beaches by waves and currents along shore lines of the postglacial lakes or sea; (4) gravel covered with thin deposits of silty clay.
3. Sand is mapped in four phases: (1) Sand in widespread but not thick sheets on the lowlands deposited during the shoaling phase of lake or sea; (2) sand, pebbly, deposited along the shore lines of postglacial lakes and sea; (3) sand littered with ice-rafted boulders; (4) sand, fluvial, deposited by flowing water on flood plains or in spillways.

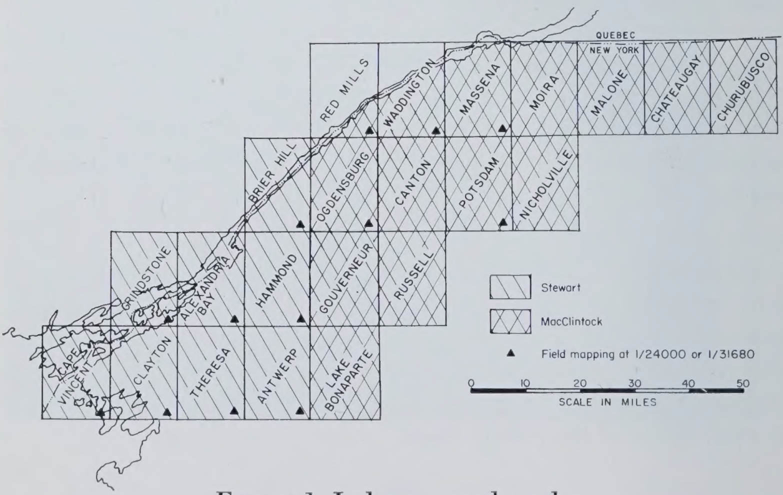
QUEBEC
NEW YORK
RED MILLS
WADDINGTON
MASSENA
MOIRA
MALONE
CHATEAUGAY
CHURUBUSCO
BRIER HILL
OGDENSBURG
CANTON
POTSDAM
NICHOLVILLE
GRINDSTONE
ALEXANDRIA BAY
HAMMOND
GOUVERNEUR
RUSSELL
CAPE VINCENT
CLAYTON
THERESA
ANTWERP
LAKE BONAPARTE
Stewart
MacClintock
Field mapping at 1/24000 or 1/31680
0 10 20 30 40 50
SCALE IN MILES

FIGURE 1. Index to quadrangles

4. Clay is mapped in four phases: (1) Clay, usually silty, deposited in the lowlands by either lake or sea; (2) clay littered with ice-rafted boulders; (3) clay, thin, deposited on flat-lying sedimentary bedrock; (4) clay, thin, deposited on metamorphic bedrock.
5. Thin discontinuous drift is mapped where only thin patches of boulders or drift lie on glaciated bedrock, either (1) horizontal sedimentary or (2) metamorphic rock.
6. Dune sand, alluvium, peat, and muck need no explanation.
7. The boundary of Fort Covington drift is mapped at the southern limit of drift, with fabric* from the northwest. But elsewhere the boundary is only approximate and is not mapped in detail. At places, it is covered by younger lake sediments and so is only inferred. South of this boundary the fabric of the till is from the northeast. Also the Fort Covington till has weathered to a buff color, whereas the Malone till has weathered to a red-brown color. Along much of this border, furthermore, the Fort Covington drift has frontal moraine topography, kames, and kame terraces.

The two authors have kept in close contact throughout the survey with frequent field and office conferences. In order to expedite the mapping of so large an area, Stewart has done most of the work west of the Ogdensburg area in the Brier Hill, Hammond, Antwerp, Alexandria Bay, Theresa, Grindstone, Clayton, and Cape Vincent quadrangles, whereas MacClintock has mapped to the east; the Canton, Russell, Potsdam, Waddington, Massena, Moira, Malone, Chateaugay, and Churubusco quadrangles.

Acknowledgments

MacClintock's field assistants were Robert Barns, David N. Lapham, Albert LaSala, John Ostrom, W. G. Summerville, and Robert Varrin.

Stewart's field assistant during 1954 was John F. Shannon. To these assistants as well as our wives, who frequently drove for us and helped in many other ways, we express our sincere thanks.

Robert O. Bloomer, of the Department of Geology, St. Lawrence University, generously put at our disposal the library and laboratory facilities of the department.

The Corps of Engineers, U. S. Army, supplied copies of the engineering report of the St. Lawrence River Project, which contains pertinent data on thickness and character of the glacial drift near the St. Lawrence River.

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* In this survey, the till fabrics were made by digging stones out of undisturbed till and measuring the long axes. Only blade-shaped stones which lay flat in the till (i.e., not up on edge) were used. The measurements are accurate to within ± 10°, which is considered enough for the purpose of the study.

S. E. Olson and R. E. Whitla were particularly helpful in looking up and discussing data and problems. John N. Harris, Director of the Soils Laboratory of Uhl, Hall and Rich, engineers for the Power Authority, State of New York, has been exceedingly helpful, both in the field and in office discussions. G. W. Brownell, E. B. Owen, and the Ontario Hydro-electric Development Corporation contributed time and information.

We have profited by field discussions with R. F. Flint, E. T. Apfel, A. L. Washburn, Nelson Gadd, Alexis Dreimanis, John Elson, Ernest Muller, Charles Denny, and Bjorn Anderson. In May 1955 and May 1957 we were the hosts to a group of about 70 "Friends of the Pleistocene" on a field conference. Paul Bird, Engineering Geologist of the Bureau of Soil Mechanics, New York State Department of Public Works, discussed geological engineering problems of the seaway. To all these people we are deeply grateful for ideas, criticisms, and discussions.

E. H. Muller has critically read the manuscript and made many helpful suggestions. R. F. Legget supplied the analysis of Malone silts. Laboratory, office, and library facilities, and clerical assistance have been supplied by the Departments of Geology at Princeton University, Marshall College, and Miami University. Princeton University also supported the survey by research grant for many incidentals and for MacClintock's field expenses in 1956 to study the new exposures of the seaway and power projects, and in 1958 to study Churubusco quadrangle and the adjacent Covey Hill Gap.

Chapter II

Advance Summary

Bedrock

The bedrock consists of Cambrian and Ordovician sedimentary rocks, which dip very gently to the north and lap onto the Precambrian Grenville rocks of the Adirondack Plateau to the south. The Precambrian rocks normally stand several hundred feet higher than the Paleozoic rocks, which have been eroded to form a broad lowland extending 20 miles from Potsdam and Canton to the international boundary at the St. Lawrence River and thence north to the Ottawa Valley in Canada.

Bedrock Surface

Outcrops and well records indicate that the surface of Paleozoic bedrock below the glacial drift is almost flat, and suggest that the region of the St. Lawrence Lowland had been reduced to a gentle plain over which the Pleistocene glaciers advanced. The many test borings for the St. Lawrence Seaway, both on the American and Canadian side, amply demonstrate the condition. Maps published by the Corps of Engineers, U. S. Army, in the *Analysis of Design for the Seaway Structure*, show a gentle fluvial topography on bedrock.

Glaciation

Early Pleistocene glaciation must have crossed this region, as shown by deposits farther south in New Jersey and Pennsylvania. Also, ice of the early substages of the Wisconsin must have crossed this region to override the whole Adirondack mountain area and extend into Pennsylvania, but no evidence has come to light within the St. Lawrence Lowland region to prove glaciation older than the late Wisconsin. No wood or other datable material has yet been found within the region, which would aid in establishing the glacial events within the standard framework of Pleistocene chronology. However, the slight amount of fluvial erosion and the shallow depth of leaching of the carbonates in the drift indicate late Wisconsin age for the glaciation. Just to the west, wood found in the sediments of proglacial Lakes Warren and Lundy, dammed by St. Lawrence Valley ice, also suggests late Wisconsin correlation.

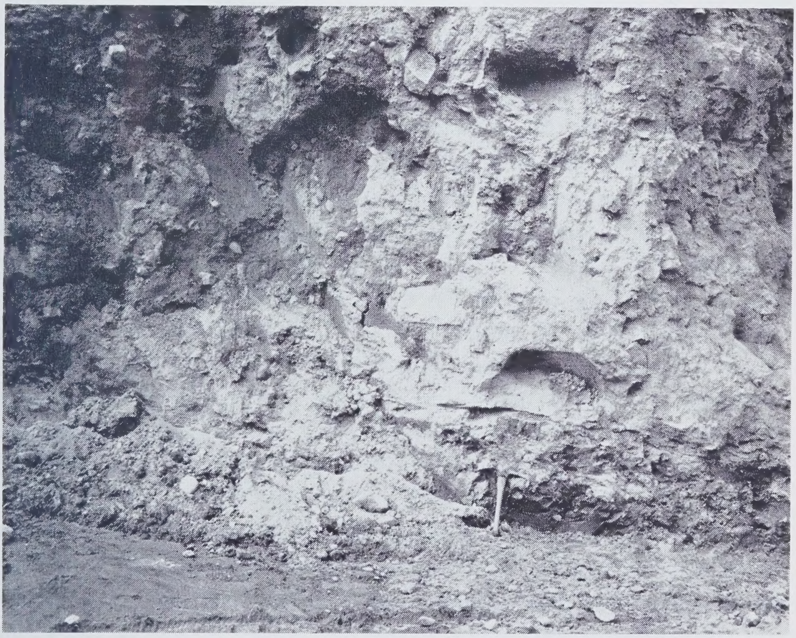


FIGURE 2. Buff Covington till lying on red-brown Malone till. Trout River bridge, $2\frac{1}{2}$ miles northeast of Malone, Malone quadrangle
Photograph by J. Heller

Two Episodes of Glaciation

Two episodes of glaciation are represented in the region. The first came from the northeast and the second from the northwest, as shown by striae and till fabric. Along the valley of Trout River, 2 miles northeast of Malone, one drift lies on the other (figure 2). The lower and earlier till is red-brown even where weathered, whereas the upper and younger one is slate-gray where fresh and weathers to a yellow-gray buff. These color distinctions are useful in the field, particularly when checked by till-fabric analyses. The southern part of the St. Lawrence Lowland contains the red-brown till and the northern part the gray-buff till. Because the red-brown drift is well displayed in Malone and environs, and there is seen to be the older of the two, it is designated as the Malone till. Because the gray-buff drift forms a major moraine whose axis passes through Fort Covington, it is designated Fort Covington till. Fort Covington Moraine is composed of Fort Covington till.

Margin of Fort Covington Drift

The southern margin of the Fort Covington till in places lies above the level of the Champlain Sea and, in these places, displays frontal moraine topography. Such topography has been largely destroyed where washed by the waves of the sea, so that the margin is indistinct. The border of the gray-buff till, from the international boundary, north of Earlville, crosses the Chateaugay quadrangle a mile north of Burke Center to Malone on the Malone quadrangle. Thence it lies south of Bangor to Dickinson Center on the Nicholville quadrangle, thence west via Hopkinton to Stockholm, where it swings southward as morainal loop on the Potsdam quadrangle, to form the striking kame-studded moraine near Hannawa Falls. From here, the boundary passes westward on to the Canton quadrangle east of Crary Mills. Here, there is another morainal loop southward into the re-entrant of the headwaters of Boydens Brook drainage. In this re-entrant, lying between Pierrepont and Waterman Hill, the edge of the Fort Covington till is marked by strong and moraine topography. The boundary lies north of Waterman Hill and along the north bank of Little River to Canton. From Canton, the margin follows southward along the frontal kame moraine bordering the valley of Elm Creek on the Russell quadrangle, as far south as Pond settlement. The kames are leached only a foot or two, and the northwest fabric shows that Gouverneur quadrangle was overrun by Fort Covington ice. From Russell quadrangle the margin passes Pitcairn, Harrisville, Natural Bridge, and thence as a lobe into the Black River Valley. It appears again west of Black River Valley on the north slope of Tug Hill through Copenhagen, following the valleys of Stebbens and Sandy Creeks to Rodman on the Watertown quadrangle.

Malone Drift

To the south of the margin thus described, red-brown Malone till is found on the uplands, accompanied by kame terraces in main valleys. These latter show stagnant-ice conditions during Malone deglaciation. The till and gravel of this drift are usually leached 5 to 8 feet, suggesting a correlation with the Cary drift of western New York and Ohio, which shows about the same leaching.

Fort Covington Drift

To the north of the margin outlined above, the gray-buff Fort Covington till is found. It forms end moraine topography south of Bangor, Malone quadrangle; north of Lake Ozonia on the Nicholville quadrangle; the Raquette River Valley south of Potsdam, Potsdam quadrangle; the Boydens Brook Valley near Pierrepont, Canton quadrangle; and Elm Creek Valley, Russell quadrangle.

Northeast-Southwest Ridges

Below the level of 500 feet occur long northeast-southwest ridges of till with sweeping smooth surfaces surmounted with beach ridges of the Champlain Sea, and interspersed with flat-bottomed lowlands floored by clay and sand. Excavations of the seaway and power projects have cut through four of these large northeast-southwest ridges. The till fabrics and bedrock striae there exposed show that the ridges are composed of a core of Malone drift, overlain by a blanket of Fort Covington drift. This belt of ridged drift enters New York State on the Malone quadrangle. Its southern margin passes southwestward near Fort Covington Center, thence diagonally southwest across the Moira quadrangle south of Bombay and north of North Lawrenceville, and on to the Massena quadrangle to include Stockholm. Here the belt attains its maximum width of 18 miles, extending northward to the St. Lawrence River. The southern edge of the belt passes Potsdam and extends to Canton, beyond which it ends near Heuvelton in the conspicuous 175′ hill of till known as Mount Lona. This hill had previously been called a drumlin, but the till fabric of the surface till is oriented southeast, normal to the long axis of the hill. The whole belt is considered as one broad moraine, with each of the hills formed normal to the ice flow. The till fabric of the gray-buff till is so dominantly from the northwest that the till evidently came to rest as a "plastered-on," "pushed-into-place" deposit rather than an ablation moraine accumulated in a pile as it fell from the melting edge of a glacier. The dearth of outwash associated with this belt also shows absence of frontal deposition. The mechanism of formation will be discussed later after evidence is presented.

Synthesis of Glacial and Postglacial Events

I. Malone Glaciation

   A. The ice moved southwest up the St. Lawrence Lowland as shown by striae and till fabric.

   B. At maximum extent the ice spread south and southwest over the Adirondacks.

II. Waning of Malone Ice

   A. As the ice margin waned from the plateau of Central New York there was a succession of ice-dammed lakes in the Finger Lake region.

   B. With further waning a lake was formed in the Ontario basin, with outlet via the Mohawk Valley.

   C. Ice on the Adirondack upland stagnated and melted downward and outward, thus ponding many small ice-dammed lakes in the valleys, as proposed by Ogilvie (1902) and by Alling (1916).

   D. In the Ontario basin and the St. Lawrence Lowland, the ice-edge stood in the waters of its own ice-dammed lake. Retreat of the ice-edge was therefore by calving of icebergs which floated away with the load of drift in the glacier. This type of retreat accounts for (1) the almost drift-free country at the western end of the lowland; (2) masses of varved clay embedded in frontal kame gravels at Redwood and Gouverneur; (3) varved lake clays studded with striated glacial stones, 2 miles southeast of Canton.

   E. This Malone retreat was pulsatory, with many slight readvances during which till was deposited over lake clay, sand, and gravel layers. It forms a recognizable unit in the seaway excavation of interstratified till, varves, sand, and gravel separated by lake deposits from the basal Malone till below.

   F. This recession reached as far as the Massena area, where till overlies varves. It probably reached Sherbrooke, Quebec, where Antevs (1925) reported till over varves.

   G. The retreat, however, apparently did not open the lowland to free drainage, because varved lake sediments are found widespread through a distance of 25 miles along the seaway project between Malone and Fort Covington tills.

III. Fort Covington Glaciation

A. A new source of ice-radiation developed on the highlands north of Ottawa, Ontario. From this center, ice spread southeastward across the lowlands and impinged against the northern slope of the Adirondack upland. The direction of this movement is shown by striae and by till fabric of the Fort Covington till.
B. Fort Covington till lies on Malone drift at Malone and in the seaway exposures.
C. Above the 500-foot level of the Champlain Sea, frontal moraine is found in south-projecting lobes at St. Regis Falls, Hannawa Falls, and Pierrepont.
D. Below the 500-foot level, morainal topography has been largely softened by Champlain Sea waves, to make the smooth surface of the Fort Covington drift overlain by beaches on hilltops and hillsides.
E. Fort Covington till lies on varves not only in the seaway excavation, but also at Coveytown Corners and near Morristown.
F. Fort Covington ice pushed against Covey Hill, and left its end moraine across the northern part of the hill to show that it must have dammed the St. Lawrence drainage high enough to overflow at the Covey Hill Gap. This occurred at the Coveville stage of Lake Vermont, which was also dammed by Fort Covington ice across the north end of the Champlain Lowland.
G. Into this Fort Covington Lake, draining at Covey Hill Gap (present elevation 1,010 feet) deltas were built by the Chateaugay, Trout, St. Regis, and Raquette Rivers. The St. Regis Delta is seen to lie on Fort Covington till at Dickinson Center, showing a slight recession of Fort Covington ice before recession at Covey Hill.

IV. Post-Fort Covington

A. Fort Covington ice waned to a position north of Ottawa (probably by claving into the ice-dammed lake), liberating an expanse of water which stood about 300 feet lower than Covey Hill Gap and which was confluent with the Fort Ann stage of Lake Vermont.
B. Into the Fort Ann Lake were built deltas at Malone, Burke Center, and Dickinson, which now stand at altitudes of 700-725 feet. On the bottom of this lake also were deposited a few feet of varved clays, which overlie Fort Covington till as far north as Ottawa.

C. The ice barrier which dammed Lake Fort Ann broke and allowed the lake to drain. Desiccation of the varved clays, fluvial erosion of the clays, and oxidation of the top of the Fort Covington till show that the lowland was dry land at this time. Sea level was still low because of withdrawal of water backed up in the ice caps.

D. Sea level rose with return of water from melting glaciers and gradually flooded the St. Lawrence Lowland and the Champlain Valley. The shore line of the marine invasion stands at present altitude of 525 feet on the north slope of Covey Hill, and 500 feet at Hermon, southwest of Canton. Deltas at Constable, Fay, West Bangor, Hannawa Falls, Pyrites, etc., belong to this episode.

E. Fossiliferous marine clay is widespread in the lowland. It commonly lies on a few feet of varved clays, but in many places it rests directly on Fort Covington till. The till is oxidized below unoxidized blue-gray clay.

F. Isostatic rise of the land, more rapid than eustatic rise of the sea, gradually brought the land to its present stand above sea level.

G. During this process of emergence, wave action has washed off the capping of fresh-water and marine clay from the summits of the hills of till, and then has winnowed out the finer part of the till to leave a blanket of stony beach material containing marine fossils, which now caps many of the till ridges. This winnowed till is heaped into storm beaches on the crests and flanks of innumerable hills. As the fine fraction in the till comprises about 75 per cent of its volume, the hills must have been lowered about 40-50 feet to make the thickness of winnowed till which is found.

H. The descending series of horizontal beaches, found on many hills, show gradual and progressive emergence. No particular level shows bigger beach ridges to suggest longer stand at that level. This same observation was made by E. B. Owen (1951b) for the area in Ontario north of the St. Lawrence River.

I. The lowlands between the till ridges were aggraded by marine clay, capped by a few feet of marine silt and sand spread by waves and rivers during the shoaling phase of the emergence.

J. Marine isobases which trend ENE-WSW ascend from 500 feet on the south side of the lowland to 700 feet just north of Ottawa, i.e., toward the source of the proposed Fort Covington outflow (see Flint, 1957, figure 14-6).

The evidence upon which this summary has been based will be presented in detail in the following pages.

CHAPTER III

Previous Studies

In order to evaluate previous work and properly credit ideas, it is worthwhile to review in chronological order the literature bearing on the Pleistocene geology of the St. Lawrence Lowland.

As long ago as 1845 Sir Charles Lyell described a beach well above the level of Lake Ontario, north of Toronto, and ascribed it to a former ice-dammed lake. James Hall, about 1843, mentioned a raised beach ridge in New York State with fresh-water shells found in the beach gravels. J. S. Fleming (1861) further described and mapped a part of the raised beach north of Toronto. J. W. Spencer (1883) described the raised beaches at the western end of Lake Ontario, and also those in New York (probably quoted from James Hall), 158 to 190 and even up to 400-feet altitude at the north end of Skaneateles Lake. In his table he attributed to Dawson a description of beaches along the St. Lawrence at 325, 378, 448, 479, 505, 660, 748, and 900 feet elevation, and said that when the study of the raised beaches shall be completed we would then know about the local and general oscillations of the continent. G. K. Gilbert (1885) published a short note on the "post-glacial changes of level in the basin of Lake Ontario" wherein he described the rise of beach ridges toward the east and northeast. J. W. Spencer (1888) proposed the name, Iroquois Beach, for this ancient shore line described by Gilbert. In 1890 he published a detailed description, and followed this with further data including a small-scale map of the beach around the Ontario basin, which showed its rise toward the northeast by spot elevations using data furnished to him by G. K. Gilbert. Even though James Hall had long before noted a rise of the beach toward the northeast, Gilbert was the first to measure it. G. K. Gilbert (1890) published a description of the Rome-Mohawk outlet for Lake Iroquois.

Spencer (1892) followed the beach northeast from Watertown (altitude 730 feet) to Fine (altitude 972 feet), and proposed that it was formed by marine waters. Gilbert in the same volume doubted his interpretation, as also later did F. B. Taylor (1897). Spencer (1894) discussed Lake Iroquois in relation to Niagara Falls. This same year S. P. Baldwin (1894) published on the Pleistocene history of the Champlain Valley, and included a map of the area.

Sir William Dawson (1894), in his book on the Canadian ice age, proposed that ice radiating from highlands combined with floating icebergs on marine waters of the lowlands would explain all the glacial phenomena of the region. He described the Laurentide Glacier as spreading southwest up the St. Lawrence Valley, but he mentioned striae trending south to southeast in the Ottawa Valley. He quoted Ells as saying that in the Appalachian Highlands of the eastern townships of the Province of Quebec striae pointed westward up the St. Lawrence Valley, and showed local glaciation as opposed to continental glaciation. This early local glaciation was followed by a newer and higher drift attributable to floating ice. Dawson described fossils collected from calcareous nodules in the clay near Ottawa: . . . "not only the ordinary shells of the deposit but skeletons of fish and a species of seal as well as leaves of land plants and fragments of wood." At Packenham Mills, west of Ottawa, several species of land and fresh-water shells were found associated with marine forms in the *Saxacava* sand. He also mentioned a whale skeleton at Smith Falls, 420 feet above sea level.

H. L. Fairchild published the first of many papers on the glacial lakes of New York in 1895. A. P. Low (1895) reported well-defined shell-bearing beds up to at least 515 feet altitude, along the line of the Quebec and St. John Railway.

R. Chalmers (1896) gave sporadic elevations of "marine" shore lines on the south side of the St. Lawrence River. In the same year, C. D. Walcott (1897) reported that G. K. Gilbert and his party had demonstrated that, at the close of the Lake Iroquois epoch, the waters had drained via the Great Gulf outlet south of Covey Hill, and descended its eastern slope to near West Chazy; also that the marine-water shore line of the Champlain Valley extended westward through the St. Lawrence Valley into the Ontario basin, where it was continuous with the "Oswego shore line." Therefore Gilbert concluded that the waters of the Niagara River emptied into a gulf of the ocean which occupied the St. Lawrence Valley. The following year Fairchild (1897) published on the glacial geology of western New York, and on Lake Warren shore line and the Geneva Beach. F. B. Taylor (1897) proposed that the shore lines of the Adirondack region were made in local ice-dammed lakes. After a field trip with J. W. Spencer, and further work himself, he reported that he saw nothing either in the Ausable and Saranac area or along the north slope of the Adirondacks that could not have been formed in lakes of small to moderate size ponded by the glacier. "There is no evidence of widespread submergence on this slope." He proposed the name of Lake Adirondack for an ice-dammed lake in the Ausable and Saranac drainage basins which formed the Wilcox, High Falls, and Dannemora Terraces. The existence of this ice-dammed lake shows that there was no ice cap on the Adirondacks at this time, only possible local valley glaciers. The erratic blocks of Potsdam sandstone, which Hitchcock reported littering the slopes of Whiteface Mountain up to 4,470 feet, would have been removed by a local ice cap. These facts show that the peripheral belt of ablation of the main ice sheet was at least 100 or more miles wide, with the névé line well back on the ice. Even the top of the Adirondack upland was below the snow or névé line, and hence no ice cap formed.

R. W. Ells (1898) described two sets of striae in Ottawa, one set trending southeast and the other southwest. He didn't, however, record which was the older and which the younger.

G. K. Gilbert (1898) mapped isobases of Lake Iroquois and Lake Nipissing. Fairchild (1898) described kettles in glacial lake deltas, and attributed them to the melting out of former ice blocks. A. P. Coleman (1899) found fresh-water shells in the Iroquois Beach at Toronto, proving Lake Iroquois to be fresh. H. L. Fairchild (1899) published the first large-scale map of the Iroquois Beach. The part in Ontario was taken from Spencer's map. A. P. Coleman (1901) "traced" the marine beach into the Ontario basin from near Prescott, Ontario, where at 350 feet he had found the westernmost marine shell fragments. A clay terrace at about this same level appears westward, and gradually descends to 297 feet at Coburg and about 216 feet near Toronto. This indicates a rise from Maitland to the shell bed at Montreal of 1.75 feet per mile. In this same paper, Coleman extended the concept of *Saxacava* sands to what he named *Saxacava* gravel. He described the latter as composed of coarse gravel, having a substratum of boulder clay, in morainic ridges but arranged by wave action. One thin sheet of this gravel on top of a drumlin west of Finch was formed as shoals in a shallow sea where wave action worked up the stones of the boulder clay into local gravel deposits.

The following year J. H. Ogilvie (1902) summarized and correlated knowledge to date. The map of striae shows the general movement to the southwest across the Adirondack area. Local lakes ponded by stagnant ice were postulated, and local valley glaciers in isolated places followed the ice cap. H. L. Fairchild (1903) described pre-Iroquois channels between Syracuse and Rome. Coleman (1904) described further the Iroquois Beach in Ontario. C. E. Peet (1904) published on the glacial and postglacial history of the Hudson-Champlain Valley. H. L. Fairchild (1904) described the direction of glacial flow in central New York. A. P. Coleman (1904b) published more on the Iroquois Beach, and supplied a fairly complete map. The next year H. L. Fairchild (1905) published a paper on Pleistocene features of the Syracuse region, with a map depicting the lake histories. J. B. Woodworth (1905b) published his bulletin on the ancient water levels in the Champlain and Hudson Valleys. He showed the beach remnants of the ancient water plane to rise northward. He reported the marine fossils as rising in altitude from

Crown Point near the south end of Lake Champlain, to Plattsburgh near the north end, and diagramed the marine shore line as rising northward at a steeper angle than the preceding lake levels. He mentioned marine fossils also in the St. Lawrence Valley at Ogdensburg and Norwood. This study of Woodworth's has been of major significance, and with only slight modification has stood the test of time. His marine shore line at 525 feet at Cove Hill and Lake Vermont shore at 720 feet still stand as our best interpretation. H. L. Fairchild (1907b) proposed the name Gilbert Gulf for the sea level waters in St. Lawrence and Ontario basin. J. W. Spencer (1907) published his views on Lake Iroquois in his description of Niagara Falls history, and H. L. Fairchild (1907c) published an abstract on the extinction of Lake Iroquois when the ice melted away from Covey Hill. H. L. Fairchild (1909) proposed names for the succession of ice-dammed lakes, in central New York, formed as the ice melted north of the divide. He gave names to seven of them prior to Lake Iroquois, which latter he thought had two stages; an earlier one which drained via the Mohawk Valley and a later one with outlet at Covey Hill. W. J. Miller (1909) published a map of the ice movement in northwestern New York, with striae south through the Black River Valley and thence eastward past Utica to Little Falls.

H. L. Fairchild (1910) described the glacial geology of the Thousand Islands region. He proposed two episodes of glaciation, with fluvial erosion between them. He likewise described the condition of the ice edge standing in the waters of Lake Iroquois, but made little mention of retreat by calving to account for the lack of deposition of drift in the region. In fact, he went to great lengths to explain this condition by lack of drift in the ice itself. J. W. Goldthwait (1911) described the 20-foot terrace in the lower St. Lawrence Valley, and named it the Micmac Terrace. He deduced (1) rapid postglacial rise of the land to bring the marine terrace to its maximum elevation of 630 feet at Quebec; (2) the Micmac stability at sea level for a long duration, possibly 3,000 years, with perhaps some slow flooding; (3) slow rise of the land to its present stand.

H. L. Fairchild (1912a) produced maps of the early stages of recession and the ice-dammed lakes. J. W. Spencer (1912) published a re-evaluation of evidence at Covey Hill which was described earlier by Woodworth (1905). Spencer gave a very good description of the region, and marshalled evidence against earlier interpretations. In the first place he contended that the "Gulf" was not made by overflow of the big lake which stripped the milewide overflow channel, but was made in postglacial time by a small stream working headward in the jointed Potsdam sandstone widened by frost action and the "Pond" was formed by ice-jam transported blocks. He furthermore pointed out that a shore line for a lake cannot be followed continuously, even though fragments of beaches and deltas are present. The shore line is therefore purely hypothetical, and is produced only on a graph by connecting the fragmental bits of evidence. Only south of Watertown are beaches continuous. He contended that the Covey Hill spillway is 50 feet above the level of Lake Iroquois, whose outlet, he maintained, was always via Rome. The floods across Covey Hill came from a lake older and higher than Iroquois. He furthermore questioned the marine origin of the 523 foot beach north of Covey Hill. The argument that shells are not found because the material is too coarse is not valid, since they are present in even coarser material not far away.

However, H. L. Fairchild (1912b) accepted the Covey Hill outlet of Lake Iroquois at 1,025 feet and the marine beach at 525 feet. This "marine" beach can be "traced" westward into New York at 520 feet north of Chateaugay. He claimed that this shore line now has been "traced" in "practical continuity" to Potsdam at 480 feet (note, modern maps show delta tops of 900, and 570-580, but none at 480). Even though his altitudes at Gouverneur are frankly extrapolations, he claims "the correlation of these beaches with those at Watertown, in Jefferson County, is now positive."

In this same publication he proposed that Lake Iroquois drained down to Lake Emmons which in turn, as ice withdrew, fell to the level of Lake Vermont, which expanded into Champlain and St. Lawrence Valleys and even Ontario Lowland. This extensive lake he proposed to call Lake Vermont-New York. Deltas are broad in the Raquette, the Grass, the Salmon, the St. Regis, and Chateaugay Rivers.

In the *Guidebook for the 12th International Geological Congress*, several papers are of interest. T. Keele and W. A. Johnston (1913) described the surficial deposits near Ottawa as two sheets of till with sand and gravel between them, and overlain by fossiliferous marine clays up to 475 feet altitude. They reported striae toward the southwest with a younger set crossing them toward the southeast. In the same guidebook, Goldthwait (1913b) described Covey Hill and environs with the upper marine limit at 523 feet, and emphasized that there is no evidence of wave work above this altitude.

The following year, J. W. Goldthwait (1914) published a brief note on the marine beaches in southeastern Quebec. Frank Taylor (Leverett and Taylor, 1915) proposed the name Lake Frontenac in the following statement (p. 325; plate XXI) "When the retreating ice opened a passage eastward around the north side of the Adirondack Mountains to the basin of Lake Champlain, the lake level fell and the outlet at Rome was abandoned. At this stage the ice barrier or dam rested about on the Frontenac Axis of Pre-Cambrian rocks and the lake may therefore be called Lake Frontenac." On page 445 they described the overflow channel at Covey Hill.

H. P. Cushing (1916) described a moraine which crosses the Ogdensburg area from northeast to southwest parallel with the St. Lawrence River. "It has been washed by post-glacial waters and has a subdued topography." Two miles south of this moraine belt stands Mount Lona, a very prominent oval hill of till. Cushing called it a drumlin, in spite of the fact that striae on his map point south to S 10°E, nearly normal to its direction of elongation. In this assignment he was evidently following Chadwick, who insisted that this hill, like those of the Canton area, were drumlins made by ice from the northeast. The morainic hills rise above the widespread clay plain that comprises much of the area. Fossils found in the clay show it to be marine. The area must have been overrun by earlier glaciers, but the striae and drift are by the last retreating ice sheet. The earlier two sets of striae trend S 40°W, crossed by a younger set S 10°W to S 10°E. During ice recession, the region was covered by Lake Iroquois water and the moraines left by the retreating ice were deposited underneath these waters. With opening of the lower St. Lawrence, seawater flooded the area. Since then, the land has slowly risen.

H. L. Alling (1916) published a significant paper describing glaciation of the central Adirondacks. He followed the earlier suggestion of F. B. Taylor (1897): "The ice-sheet melted first around the mountain peaks and retreated down the slopes forming irregular rings that held glacial waters. Melting has produced a long succession of lakes, each with deltas, beaches, and outlets." By diagram he showed the water plains rising northward at 2 feet per mile.

H. L. Fairchild (1916b) published again on uplift in New York and New Hampshire.

W. A. Johnston (1917) gave one of the first detailed descriptions of the Pleistocene deposits of the Ottawa region. He included measured sections of the surficial deposits and a simple "soil" map. He found two sets of striae, the first set due south and a later set crossing them toward the southeast. The till is gray where it lies on Paleozoic limestone and shale, and where it rests on crystalline rocks or on sandstone. On both till and bedrock, marien fossiliferous clays and sands are found. Two clay layers are separated by sand and sandy silt. The upper clay overlies the lower up to at least 425 feet. The overlying sands he attributed to the shoaling episode with fluvial sands below 240 feet. R. W. Ells (Appendix) gave long lists of fossils from the concretions found in the clay, which include birds, fish, chipmunk, and even a fresh-water shell. The lower clay contains an abundant fauna of Arctic species, whereas the upper clay has fewer and less characteristic forms.

Fairchild (1917) described the area north of Albany as covered by a delta built into sea level waters by Mohawk outlet waters. He maintained that since Round Lake and Saratoga Lake are ice-block depressions, no large river ever flowed south out of Champlain basin, and therefore the lower St. Lawrence was open when the Fort Edward-Whitehall area was liberated from the glacier. In 1918 he published further on postglacial uplift in northeastern North America, with maps of isobases.

In 1919 Fairchild published a series of maps portraying his concept of the sequence of ice-dammed lakes. In this publication, he confused the whole problem badly by assuming that all the beaches of the Champlain Valley were the result of wave action in a narrow sea level strait extending from New York to Montreal. He drew only one water plane (plate 10, Fairchild, 1919b) from sea level at New York to 740 feet at Covey Hill. He produced this plane by connecting the highest beaches of each vertical series. All the inferior beaches he thought were made as the land rose. Later work, especially Chapman (1937), has shown the upper beaches to be lake shores and the marine beach to be down at 525 feet at Covey Hill, as Fairchild himself had correctly placed it in 1912. If this be corrected, his plate 5 of the 1919 publication becomes intelligible.

Chadwick (1919) had found shore line features in mapping the Canton quadrangle which were lower than the Iroquois shore line should have been, but higher than the marine level should have been, so after talking it over in the field with Fairchild he proposed another lake called Lake Emmons. Nothing has been heard of it since. Chadwick proposed beaches as follows: Lake Iroquois, 860 to 890 feet; Lake Emmons, 690 feet; Lake Vermont-New York, 500 to 600 feet, Gilbert Gulf, 460 feet downward. In this same bulletin, Chadwick made much of his idea that the till of the St. Lawrence Valley has been "drumlinized" by ice coming from the northeast. He accounted for the south to S 10°E striae by saying that the ice edge had a "spreading" motion that carried it around to the southward. He made little or nothing of wave erosion of the till, even though he discussed both lake shores and marine submergence.

H. L. Alling (1921) published a good account of the high level ice-dammed lakes in the Mount Marcy area of the Adirondack Mountains. E. W. Kindle (1922) published on the Ottawa Beach of the Champlain Sea, and W. Goldring (1922) described the fossils of the Champlain Sea and found a decrease in number of species, as well as dwarfing, toward the south in the Champlain Valley and toward the southwest in the St. Lawrence Valley. She attributed this to lower salinity near Crown Point and Ogdensburg. J. H. Cook (1924) published an important paper on glacial stagnation during recession of the last ice sheet from eastern New York. He based his argument on the work of R. D. Salisbury (1902) in New Jersey, of F. G. Clapp (1904), and M. L. Fuller (1904) in Massachusetts, and extended the concept to make an effective case for stagnation over a wide region. In fact, he proposed that all that part of the ice sheet south of the St. Lawrence Lowland waned by stagnation. "It is doubtful if there is an unequivocal frontal moraine marking a halt in retreat of a moving ice sheet throughout the whole length of the Hudson and Champlain valleys." F. B. Taylor (1924) published a small-scale crude map of what he proposed as "moraines" of the St. Lawrence Valley. He "traced" an "Oswego moraine" northward to Watertown and thence northeastward until he "lost it in the Adirondack forest." He mapped ice motion arriving normal to his postulated moraines by having the ice come southwest up the St. Lawrence Valley, and then spread to the south at its margin. The glacial hills of the Canton-Massena area he called drumlins, even though he showed them parallel with his moraines. It is too bad that he abandoned his earlier idea of glacial stagnation (F. B. Taylor 1897) without presenting evidence and discussion, for he now seems to have had elements of truth in both papers.

The following year H. H. C. Martens (1925) described the distribution of glacial boulders in northern New York. He pointed out that the characteristic boulders from the Monteregian Hills, and other rocks of the southeast townships of Quebec, are conspicuously more numerous at a distance of 8 to 10 miles southeast of Ogdensburg than they are within a mile or 2 of the St. Lawrence River. This might be considered a forerunner of the idea of two ice invasions, one from the northeast and one from the northwest. H. P. Cushing and D. H. Newland (1925) found no moraines in the Gouverneur quadrangle and very little drift, only a thin covering of lake clays. Antevs (1925) quoted from Fairchild that Lake Iroquois first drained via Rome and later via Covey Hill. He then proposed that when the ice liberated the north slope of Covey Hill, Iroquois fell to the level of Lake Vermont and cited Fairchild (1918, plate 5), and Woodworth (1905) as describing beaches of this stand at 740 feet. This statement is confusing, because Fairchild's plate 5 very explicitly marks the 740 foot shore line as "marine shore." Antevs likewise confused the reader by saying "The subsequent water body west of Covey Hill, at the same level as Lake Vermont is called Lake Frontenac." As earlier stated, Leverett and Taylor (1915) had proposed the name Lake Frontenac for the water body held by the ice edge standing on the Frontenac axis, and whose waters drained across the Covey Hill spillway into Lake Vermont in the Champlain Valley. Furthermore, Fairchild (1912) had proposed the name Lake Vermont-New York for the expanded water body with beaches and deltas now about 730 feet west of Covey Hill. Antevs' evidence of a lake in the St. Lawrence-Ottawa area prior to marine invasion is substantiated by later studies, but his choice of name for this water body was incorrect. Antevs proposed that the invasion of the sea occurred shortly after the uncovering of Ottawa, while the ice front ran somewhat south of the junction of the Ottawa and St. Lawrence Rivers through southeastern Quebec north of Sherbrooke. In this region there was readvance, for near Angus, 15 miles southeast of Sherbrooke, varved clay is overlain by till (Antevs, 1925, p. 65). Since the St. Lawrence and Champlain basins are favorably situated to have accumulated fine-grained sediments, the finding of only thin deposits of varved sediments shows this lake to have been relatively short lived. Confirmation has come, during present study, in exposures of 5 feet of varved clay containing 60 to 80 winter layers in several of the new excavations for the St. Lawrence Seaway. He postulated that the waters of the Frontenac-Vermont Lake drained across the ice in the lower St. Lawrence, and helped to weaken it for the sea to break through and thus leave a large ice mass southeast of the St. Lawrence. H. L. Alling (1921) reconstructed the history of a succession of ice-dammed lakes in the Adirondack valleys during waning stages. W. J. Miller (1926) published a map showing striae toward SW on Lyon Mountain.

J. W. Goldthwait (1926) described evidence of erosion between two bodies of marine clay in the Ottawa region caused by rising and falling of the region as it came up to its present position. A. P. Coleman (1927) described two glaciations in the St. Lawrence region with fossiliferous marine deposits between two tills. Restudy of Coleman's localities, however, during the present study has failed to confirm Coleman's deductions. Coleman described the material above the shell-bearing sands as "stony till with broken shells." This kind of material is very common in the St. Lawrence region, and was made by waves and currents of the Champlain Sea washing out the finer material of the till. It is called "winnowed till" in the current report.

A. P. Coleman (1932) published a detailed description of the Pleistocene of the Toronto region, but added no new ideas to the history of the general region; H. L. Fairchild (1932) published more or less of a summary of his ideas on the glaciation of New York State, with a fairly good bibliography.

A. F. Buddington (1934) published maps of the Hammond, Antwerp, and Lowville quadrangles showing striae, recessional moraine tracts, and deltaic deposits in ice-dammed lakes. In his maps and description of the Potsdam quadrangle, J. C. Reed (1934) followed Fairchild's (1918) interpretation of shore lines: Iroquois rising eastward from 840 at the west to 920 at the east, and the marine shore from 600 at the west to 620 at the east edge of the map. He followed Chadwick in describing the glacial hills in the northern part of the quadrangle as drumlins because of their rounded elongate shape. A. P. Coleman (1936) published a large and detailed map of the Iroquois shore in Ontario. He proposed that the small fresh-looking moraines show that the glacier-margin stood at the Thousand Islands at Lake Iroquois time.

D. H. Chapman (1937) published a careful study based on precise leveling of the shore lines in the Champlain Valley. He confirmed Woodworth's (1905b) interpretation of two stages of Lake Vermont above a marine shore line. The upper shore he still called the Coveville stage, draining at the Coveville outlet, but the lower one he named the Fort Ann stage, with outlet waters at Fort Ann instead of Fort Edward as Woodworth had placed it. The three shore lines are parallel in their rise toward the north, showing that uplift did not begin till after Champlain Sea time. J. W. Goldthwait (1938) published a discussion of stagnant ice in New Hampshire, and suggested that the marine limit along the Atlantic shore is obscure because the ocean rested against stagnant ice masses. G. M. Stanley (1938) published his account of the submerged channel through the Straits of Mackinac. He proposed that, by cutting the channel, the Mackinac River drained the Lake Michigan basin down to the Bowmanville low water stage. This concept involved recession of the ice far enough at least to liberate the Straits of Mackinac, prior to the readvance of Valders ice to bury the Two Creeks forest bed.

E. Antevs (1939) suggested that parallel beaches of the Great Lakes were formed during times of stillstand, whereas beaches which diverge northward show times of uplift. For the St. Lawrence Lowland, he assumed parallelism of the Iroquois, his so-called Lake Frontenac and Champlain Sea shore lines, and suggested that quiescence prevailed through Lake Iroquois, Lake Frontenac, and into Champlain Sea stages. Chapman had proposed the same episode of quiescence in the Champlain Valley. Antevs enlarged upon the observation of W. A. Johnston (1917) of two marine clays in the Ottawa area, and proposed that the two clays are the product of two marine episodes with submergence and erosion between. He proposed that since the upper clay is not found above the 240 foot level, the second invasion rose only this far. His second marine invasion he proposed to call the Ottawa Sea. The sections he described are compatible with the hypothesis of an Ottawa Sea, but contain no real proof of a subaereal erosional interval to establish unanimity of opinion on the matter. The literature is still confusing, and the old exposures are now badly slumped. The Canadian Geological Survey is planning a careful restudy of the area and the problem.

L. J. Chapman and D. F. Putnam (1940) published a paper describing ice movement toward the south in the eastern part of Ontario, and swinging toward the southwest in the western part. They attributed the change of direction to the influence of the St. Lawrence River. A. E. Wilson (1946) discussed the Ottawa-St. Lawrence Lowland bedrock stratigraphy and structure, and gave only cursory attention to the Pleistocene deposits of terminal moraines and drumlins overlain in lower places by varved clays denoting ice-dammed lakes, and by Champlain fossiliferous clays and sands. She described beaches at various levels. This same year she published a small map of a buried channel of the St. Lawrence River south of Barnhart Island, based on the engineers' borings. C. P. Berkey (1947) studied the effects of the Massena-Cornwall earthquake for the U. S. Corps of Engineers. He published a short note confirming that the damage was related to geological conditions, i.e., least damage to structures on bedrock, next on till, next on gravel, and most on marine clay. His report to the engineers showed the Pleistocene deposits on the northern part of the Massena 1:62,500 scale map. The northeast-southwest ridges of till he called moraines, between which he then found outwash gravel covered with 20-50 feet of marine clay and a few feet of sand. He mentioned boulder-strewn beach areas, but did not map them. L. J. Chapman and D. F. Putnam (1951) published an extensive physiography of southern Ontario in which they described and mapped much of the Pleistocene of the St. Lawrence Lowland in Ontario. They interpreted the history on the basis of one Wisconsin glaciation, breaking up into lobes during deglaciation. They followed their earlier idea of southward-flowing ice near Cornwall turning to southwest movement parallel with the St. Lawrence, and depositing northeast-southwest drumlins, followed by Lake Iroquois and Champlain Sea.

E. B. Owen (1951a), in studying the area on the north side of the St. Lawrence for ground water, produced the first detailed map of the glacial and postglacial deposits of the region. He mapped low, elongate northeast-southwest ridges of till rising above flat clay-filled lowlands. He reported that the till ranges from bluish-gray compact to dark-brownish less compact material, and considered it all one till sheet. He found, not uncommonly, in well records, a few feet of outwash gravel below the marine clay. He found a few feet of varved fresh-water clays below the marine clays, and followed Antevs (1925) in attributing them to "Lake Frontenac" which covered the area following the retreat of the ice sheet and before marine invasion. The marine deposits he described as a score or more feet of marine clay and silty clay overlain by a few feet of marine sand in the lowlands, and a few feet of fossiliferous, reworked, sandy, gravelly till on many of the till hills. Raised beaches of the Champlain Sea occur at many places, ranging from about 240 feet to 363 feet in elevation. He gave a table to show the range of elevations, and reached the conclusion that since no beaches are noticeably more pronounced than others, the rise of the land was a slow continuous process without noticeable pause. He followed Chapman and Putnam (1940) in considering the till hills to be drumlins deposited parallel with direction of glacier motion, which was southerly in the eastern part of the area and southwesterly in the western part.

E. F. Osborne (1951) proposed an ice cap radiating outward from the Parc des Laurentides highland, during late glacial time, which deposited till over Champlain marine fossiliferous clays in one or more areas. He suggested that the local ice cap may have been contemporaneous with Antevs' Cochran readvance. Controversy exists over some of Osborne's interpretations.

Nelson R. Gadd (1953) found interglacial peat at St. Pierre, Quebec, between Montreal and Quebec City which was first dated at 11,000, C^{14} years suggesting it to be of Two Creeks Age. Later analyses of the same material indicated age greater than 30,000 C^{14} years (Preston, and others, 1955) and greater than 40,000 C^{14} years (Rubin and Suess, 1955), indicating a pre-Wisconsin date for the peat.

During the same year, E. B. Owen (1953) published another detailed map of the drift on the north bank of the St. Lawrence. Owen found no evidence for subdividing the Wisconsin glaciation of the St. Lawrence region.

R. F. Flint (1953) proposed that since Cary ice receded north of the Straits of Mackinac in Two Creeks time, an equivalent recession from the Cary Moraine in southern New York State would have carried it north of Ottawa to leave the St. Lawrence Valley free of ice during Two Creeks time. He proposed that the St. David Gorge at Niagara Falls may have been cut at this time. He suggested a Mankato ice readvance through the Ontario basin to fill the St. David Gorge with Mankato drift. Flint cited Coleman (1927; 1932), who described marine fossils incorporated in till at Waddington and at Cornwall, as evidence that the sea invaded the St. Lawrence Lowland in Two Creeks time to depost fossiliferous clay which was overlain by readvance of Mankato. (The present writer, however, re-examined Coleman's localities, and could find no fossils in the till itself. Thousands of observations of till at the surface and in multitudes of borings have failed to show any marine shells in the till.) Flint would have Mankato ice advance to Glens Falls in the Champlain Lowland to produce crumpling of lake sediments near Fort Edward (Woodworth, 1905b). By connecting this margin of Mankato advance northward around the Adirondacks to the possible stand in the

Ontario basin, he proposed to fill the St. Lawrence Lowland with Mankato ice. Flint followed Antevs (1925, 1939) in having a "Lake Frontenac" follow ice recession to deposit a relatively thin layer of varved clay on the till, prior to the invasion of the Champlain Sea. He also pictured an emergence with erosion followed by submergence in the Ottawa Sea. Flint proposed that the warmer climate fauna and flora reported from the Ottawa lowlands actually belong to the Ottawa Sea deposits, and possibly represent the thermal maximum.

J. L. Hough (1953) discussed a low-water stage of Lake Chicago and Lake Huron during Two Creeks time, and proposed an ice-free and marine-flooded St. Lawrence-Lake Ontario Lowland that was prior to a Mankato ice advance to the Niagara Falls Moraine. He considered Lake Iroquois to be post-Mankato in age. P. MacClintock (1954a) proposed that Cary ice overrode the Adirondacks, but that Mankato ice only crossed the St. Lawrence Lowland and impinged against the northern slope of the Adirondacks. R. F. Flint (1955) dated by radiocarbon the Mankato advance into the Lake Ontario basin. C. L. Horberg (1955) concluded from radiocarbon dates that Mankato is older than Two Creeks peat, and therefore significantly older than the Valders drift which overlies the Two Creeks Forest. It follows, therefore, that east of the type section in Wisconsin the post-Two Creeks drift is correlated with the Valders. J. H. Bretz (1951) showed that Valders is younger than Port Huron east of Lake Michigan, and J. H. Zumberge and J. E. Potzger (1956) suggest the name Port Huron be used rather than Mankato for the drift immediately before Two Creeks time, in the region east of Lake Michigan. R. F. Flint (1956), from new radiocarbon dates, placed the Valders maximum at 10,700 years ago. He contended that the radiocarbon dates of the shells in Champlain Sea sediments cannot be correct in indicating age of 10,000 to 11,000 years because they follow Lake Iroquois which in turn postdates Lakes Lundy and Toleston (dated at 8,500 C^{14} years). He proposed, therefore, that the Champlain Sea existed about 7,000 C^{14} years ago. J. L. Hough (1958) summarized the history of the Great Lakes, and proposed Valders readvance across the St. Lawrence and Ontario Lowlands as far as Niagara Falls Moraine, with Lake Iroquois following the recession of this ice. He accepted Zumberge's suggestion, called the pre-Two Creeks invasion Port Huron, and projected it into Lake Erie basin at the Gault Moraine. D. P. Stewart (1958) described the ice edge of Lake Wisconsin glaciation against the northern flank of Tug Hill south of Watertown; this he considered the last glaciation of the St. Lawrence Valley. A. Dreimanis and J. Terasmae (1958) described the stratigraphy of Wisconsin glacial deposits in the Toronto area, and demonstrated Valders invasion on the Ontario basin.

Karrow, Clark, and Terasmae (1961), from the date of 11,510 ± 240 years for wood buried below Lake Iroquois Beach at Hamilton, Ontario, conclude that Lake Iroquois was formed during the retreat of Port Huron ice and that Valders drift boundary lies north of Lake Ontario.

Chapter IV

Geography

Climate

The St. Lawrence area lies in the climatic zone designated as *Humid Continental* with cool summers (*Dfb* of the Köppen system). January temperatures average 13°F and July temperatures about 69°F (Clayton, 1927). This means that commonly there are long cold spells in the winter, and that summers are mostly pleasant with a few hot spells of a week or so. There is enough rain (3.5 inches per month) so that dairying and crops grown mostly to support this industry flourish. Corn and grass silage are the most important winter feed.

Soil

The soils are classified as part of the *Gray-Brown forest* group. The U. S. Department of Agriculture has mapped the soils on inch-to-the-mile maps in great detail (Lounsbery and others, 1925). In St. Lawrence County, the map made in 1925 distinguishes 40 soil types. Some of these, however, belong to three groups: (1) soils of loose, friable consistency and open structure, of the Colton, Merrimac, Rubicon, Saugatuck, and Hinckley series; (2) soils showing slight compactness in the subsoil, of the Gloucester, Hermon, Parishville, Madrid, Lyons, Whitman, Farmington, Ondawa, and Podunk series; (3) soils with a heavy compact subsoil, of the Vergennes and Dunkirk series. Whereas the soil map does not specify the parent material, the geologist finds that Gloucester, Hermon, Whitman, and Parishville soils lie on glacial till which has little or no lime, and is derived either from Precambrian terrain, or older leached till; Madrid, Lyons, and Farmington soils lie on calcareous till lowlands; Vergennes, Dunkirk, Allendale, and Granby lie on marine clays; Merrimac, Colton, Saugatuck, and Rubicon lie on lacustrine sands; Podunk and Ondawa occupy alluvial flats along present rivers.

The new map of Jefferson County (Knox, 1952), groups the soils into soil associations, combining the concepts of the great soil groups of (1) *alluvial* soils, (2) *Gray-Brown forest* soil, (3) *Gray-Brown Podzolic* soil,

(4) *Podzol*, (5) *wet* soil, and also the geologic parent material such as till, lacustrine clays, silts, sands, or outwash gravels. The modern classification into catenas is likewise used for a group of soil series developed from the same parent material, but differing in drainage from well-drained to poorly drained conditions.

Franklin County has been recently remapped, and the report should be published shortly.

Drainage

The northern edge of the Adirondack upland is drained northward to the St. Lawrence River by the following major rivers from west to east; Indian, Oswegatchie, Grass, Raquette, St. Regis, Salmon, Trout, and Chateaugay. All have a similar pattern northward out of the highlands, and thence turning northeastward to follow the "grain" of the glacial hills in the lowland. This fact amply demonstrates that at least these lower courses are postglacial and consequent on the glacial deposits. The innumerable lakes and swamps in the headwaters of these rivers assure them of the very uniform flow. Like the St. Lawrence, these rivers have accomplished very little erosion of the till in the northeast-trending portions of their valleys. There has been some dissection of the clay fillings of the lowlands by the rivers and by their tributaries. The striking exception to the small amount of river erosion is found in the valleys of the Salmon, Trout, and Chateaugay. These rivers have cut small box canyons as much as 75 to 100 feet deep into the slabby Potsdam sandstone. This occurs where the rivers have steep gradients across jointed sedimentary rocks. The Chateaugay River, for instance, drops from its source in Chateaugay Lake (1,300 feet above sea level) to the St. Lawrence Plain (300 feet elevation) in just 15 miles, or gradient of 67 feet per mile.

Both large and small lakes are present in the western part of the lowlands, where small drift dams block preglacial drainage. These lakes are usually quite shallow. The exceptions, however, are Sylvia and Trout Lakes on the Gouverneur quadrangle. These lakes lie in soluble metasedimentary terranes, and mine exploration borings seem to suggest solution (Brown, 1936). No lakes are found in the lowland east of Ogdensburg.

Bedrock

Bedrock (Cushing, 1916; Chadwick, 1920; Wilson, 1946) consists of early Paleozoic limestone, sandstone, and shale except where the Frontenac Axis of Precambrian metamorphic rocks crosses the lowland in the area of the Thousand Islands. The surface of the bedrock has very slight relief. Test drilling in the international rapids section of the seaway project makes it possible to construct a topographic map of the top of bedrock (figure 3). This map shows a valley 60 to 70 feet deep and a mile wide. The St. Lawrence River flows on rock ledges at Rapids Flat and Gallup Rapids.

CHAPTER V

Physiography

Physiographic Setting

The St. Lawrence Lowland area forms the northern section of the St. Lawrence Valley physiographic province (Fenneman, 1930). It is the broad area, less than a thousand feet in altitude, lying between the Adirondack province on the south and the Laurentian Plateau on the north, through which the St. Lawrence River flows on its way from Lake Ontario to the sea (figure 4). Since it has occupied its present location in postglacial time, the St. Lawrence River has not had enough time to cut a valley for itself. It is simply a spillway of Lake Ontario, pouring around and among the small bedrock hills at its western end and the hills of glacial till farther east. Consequently, it is ungraded and is studded with rapids, such as the Gallup and the Long Sault Rapids. In the latter case, the river descends 82 feet in about 3 miles.

Because the St. Lawrence issues from Lake Ontario, it is not subject

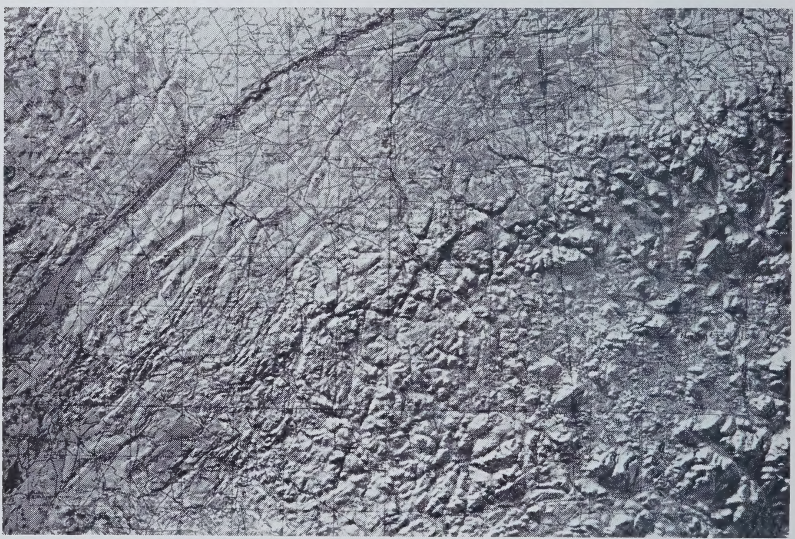


FIGURE 4. Relief map of St. Lawrence Lowland

Army Map Service

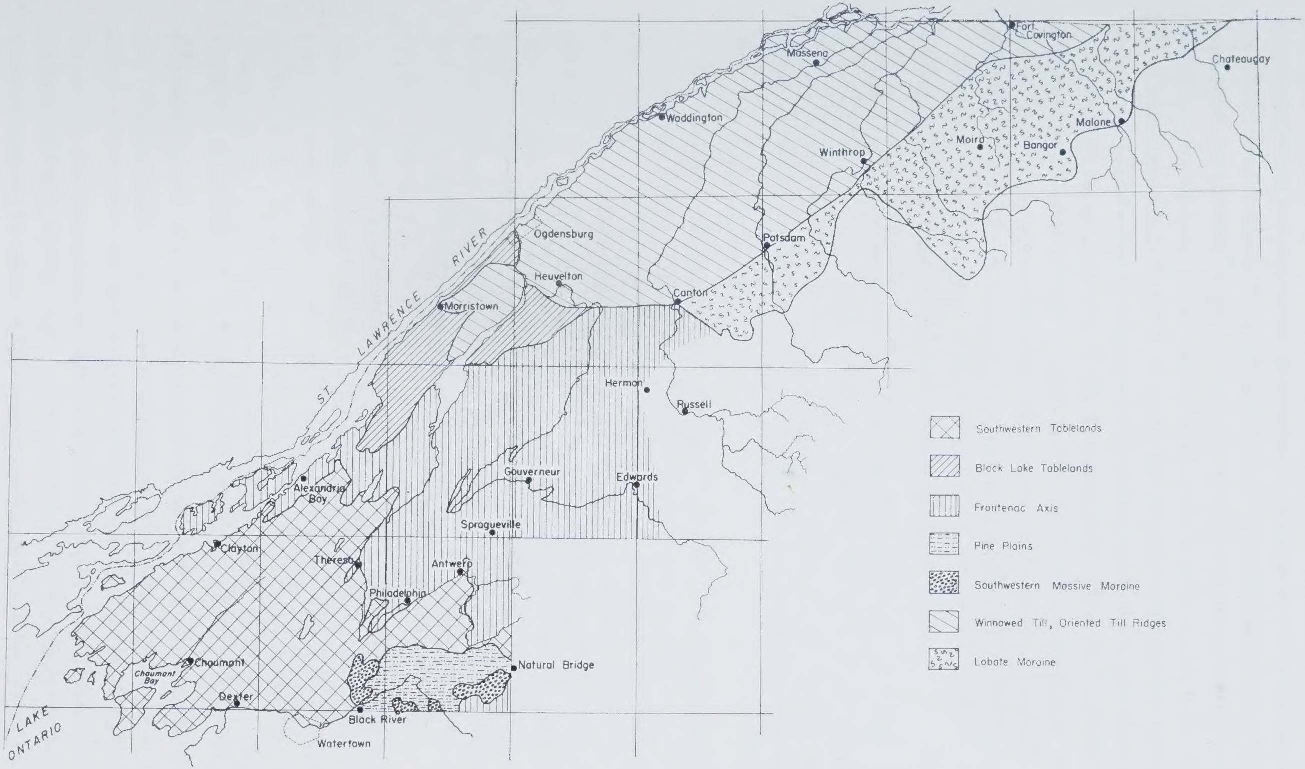

Fort Covington
Chateaugay
Massena
Malone
Waddington
Moira
Bangor
Winthrop
Potsdam
Ogdensburg
Heuvelton
Canton
Morristown
ST. LAWRENCE RIVER
Hermon
Russell
Gouverneur
Edwards
Alexandria Bay
Sprogueville
Clayton
Theresa
Antwerp
Philadelphia
Chaumont
Chaumont Bay
Natural Bridge
Dexter
Black River
Watertown
LAKE ONTARIO
Southwestern Tablelands
Black Lake Tablelands
Frontenac Axis
Pine Plains
Southwestern Massive Moraine
Winnowed Till, Oriented Till Ridges
Lobate Moraine

FIGURE 5. Index map of the physiographic subsections

to extreme floods and low water as are normal rivers. By eroding fine material which its normal flow can handle, it has left the coarser material as an armor protecting the banks from further erosion. As a result, the St. Lawrence has accomplished remarkably slight erosion for so large a river. The lowlands are underlain for the most part by flat to gently dipping Paleozoic sediments, the erosion of which has given rise to the lowlands. The region has partaken of the physiographic history of eastern North America with widespread Tertiary peneplaination, followed by uplift and degradation of the softer rocks to flat-bottomed lowlands. The late Tertiary erosion surface was still intact with only gentle valleys, less than a hundred feet deep, when it was overrun by the Pleistocene glaciers.

Physiographic Subdivisions

South of the international boundary, the lowland exhibits several types of topography different enough to allow subdivision into subsections. Even though the boundaries are not everywhere simple to draw, the characteristics of each of the following subdivisions are fairly diagnostic (figure 5):

Subsections

I. Western tableland
II. Frontenac axis
III. Black Lake tableland
IV. Pine Plains
V. Southwestern Massive Moraines
VI. Oriented till ridges
VII. Lobate Moraine
    Boyden Brook lobe
    Raquette River lobe
    St. Regis River lobe
    Bangor lobe
    Salmon River lobe

Area of Bedrock Topography Exposed by Calving Retreat

The Western tableland, the Frontenac axis, and the Black Lake tableland subsections constitute a region where the bedrock details of a strongly glaciated lowland have been exposed to view. This unique surface exists because the melting ice margin stood in a lake, so that calving icebergs carried away drift which otherwise would have covered the bedrock.

The most conspicuous characteristics of this part of the lowland are: (1) the rare occurrence and small bulk of the till deposits; (2) the large areas of bedrock exposed; (3) the close relationship of the surface topography to bedrock structure; and (4) the predominance of lacustrine sediments which lie directly on the bedrock. The most important of these characteristics, from the point of view of the Pleistocene geologist, is the fact that no large or thick accumulations of till occur in the area. Since the region has been subjected to repeated glaciation, widespread morainic structures would normally be expected to form the backbone of the topography. This is not the case here, however, and the area is essentially lacking in deposits of till.

Boundary

The southern boundary of the calving area lies along the Black River eastward from Lake Ontario to the village of Black River. The margin swings north from Black River around the Black River—Evans Mills Moraines to Evans Mills and thence southeastward to Leraysville, where the surface is overlapped by the sandy sediments of the Pine Plains. From Leraysville, the boundary follows the contact of the Pine Plains northeastward to Sterlingville and thence eastward via Reedsville and North Wilna to Natural Bridge.

The eastern boundary of the calving region, in the area mapped, approximately follows the eastern margin of the Antwerp sheet to the northeast corner of the quadrangle, and then the southern margin of the Gouverneur and Russell quadrangles to the point due south of East Edwards. The area exposed by calving retreat continues southeastward into the adjacent quadrangles that were not surveyed during this investigation. From the locality south of East Edwards, the eastern boundary follows closely the western edge of the Russell quadrangle northward through Edwards and Hermon, thence northeast to Pyrites where it swings north to Canton.

The northern boundary, from the northeast corner of the section at Canton, follows the Grass River for a few miles in a northwesterly direction and then swings southwest to Rensselaer Falls, and thence westward to Black Lake. It follows the Black Lake depression to Edwardsville, where it turns northward to Morristown. From Morristown the boundary follows the St. Lawrence River, to include the Thousand Islands to Lake Ontario.

This area thus covers all the Cape Vincent and Clayton quadrangles; the Theresa quadrangle, except the extreme southeast corner; and the northern two thirds of the Antwerp sheet. It also includes the entire areas of the Grindstone, Alexandria Bay, Hammond, and Gouverneur quadrangles; the southern one third of the Brier Hill sheet; the southwestern corner of the Canton and the western edge of the Russell quadrangle (figure 5).

I. Western Tableland Subsection

At the western end of the province, fringing Lake Ontario and extending some 20 miles eastward to the vicinity of Clayton and Theresa, is the Western tableland subsection (Buddington, 1934). The topography is composed of broad flat-topped hills of flat-lying Paleozoic sediments. Stream valleys dissect the terrain into steep-sided mesa-like hills. The mesas are marked occasionally by low scarps where the topography rises from one bed to the top of the next higher one. The tablelands are covered with a thin deposit of lake clays, silts, and sands usually only a few feet thick; in many places the bedrock is bare over a square mile or more. The surface is strewn extensively with erratic boulders. Here and there are a few scattered kame hills of gravel, and a few patches of till. One of the striking phenomena of this area is that the stream valleys cut into the bedrock have not been filled with glacial drift. Many of the capacious valleys either have no stream at all in them or only an insignificant trickle of water, which obviously couldn't be the agent which excavated the valley as we see it today, or could not have stripped out a filling of glacial drift if it had ever been present. Many of the depressions contain only a thin bottom coating of varved lake clays lying on bedrock. There is everywhere abundant evidence that the region has been overrun and heavily scoured by the glacier; when recession took place, glacial drift was deposited in only a few places, however.

The reason for these aspects of the tableland topography is that the region was liberated from the ice while the edge stood in the waters of an ice-dammed lake. The ice edge calved into the lake and floated away as icebergs. They carried with them the load of glacial drift distributing it widely over the Lake Ontario basin, rather than depositing it as a mantle of drift over the bedrock where the ice had melted on land.

II. Frontenac Axis Subsection

This area was named long ago for the early fort and village at the present site of Kingston. The Frontenac axis is a belt of Precambrian rocks which constitute a link at the surface between the Precambrian uplands of Ontario and those of the Adirondack province. It crosses the St. Lawrence River at the Thousand Islands, producing the varied and picturesque patterns of these islands. The Frontenac axis is the axis of an anticlinorium, trending NW-SE across the river at about Alexandria Bay, from which Paleozoic sediments have been partly stripped to expose the Precambrian basement. The topography of the Frontenac axis is very distinctive. In general it is quite flat, but in detail it is somewhat rough. Hills of Precambrian metamorphic and igneous rock, rounded and smoothed at their crests, rise 30 to 50 feet above broad, flat, clay-filled lowlands through which streams wander aimlessly in valleys a few feet deep between swampy areas. To this type of topography north of the river, in Ontario, Chapman and Putnam (1951) gave the descriptive name of "knobs and flats."

In numerous localities of this subsection, outliers of the Potsdam sandstone form flat tops of the higher hills. The sandstone was deposited unconformably upon the gentle topography of the Precambrian peneplain, and originally covered the entire foothill belt of the Adirondacks. The patches of Potsdam sandstone are therefore erosional remnants left during post-Cambrian dissection of the region.

The Frontenac axis subsection is composed of two major areas. The smaller of these includes the Thousand Islands, and the strip of crystalline rock along the St. Lawrence River between Fisher's Landing and Chippewa Bay. The second and larger mass is east of Black Lake and a line drawn north and south from Redwood to Evans Mills. The two areas are connected, however, by a narrow neck of crystalline rock, less than 1½ miles in width, located 4½ miles north-northwest of Redwood at the head of Crooked Creek. The surface of the Frontenac axis subsection is carved into ridge and valley topography. The ridges are generally small and low in the locality where the Grenville rocks are at the surface, but are higher and more massive where they are composed entirely of igneous rock, particularly granite, or are capped by Potsdam sandstone.

The ridges are aligned in a northeast-southwest direction, parallel to the trend of the regional structure. The glacial ice which covered the area moved across the ridges at various angles, as shown by striae, in some areas oblique and other localities acute. The regional aspects of the topography were affected only to the extent of etching out soft or jointed rock to bring the grain of the structure into relief (figure 6).

Many geologists have assumed that the trend of the ridges parallels the ice direction. The present study of striations in this area clearly shows this not to be true. The conclusion that bedrock has been the most influential factor, does, however, agree with the findings of Zumberge (1955), who studied glacial erosion in areas of tilted strata and was able to report with confidence that the structure, especially the jointing of the rock, was the controlling factor. These conclusions are also in accord with those of Buddington (1934, p. 24) who contends that the ice "merely modified" but did not "produce the major feature" of the topography.

Direction of Ice Movement

Striae recorded by former investigators suggested ice movement southwest through the axis of the St. Lawrence Valley, approximately parallel to the present course of the river, and spreading from this axis toward the

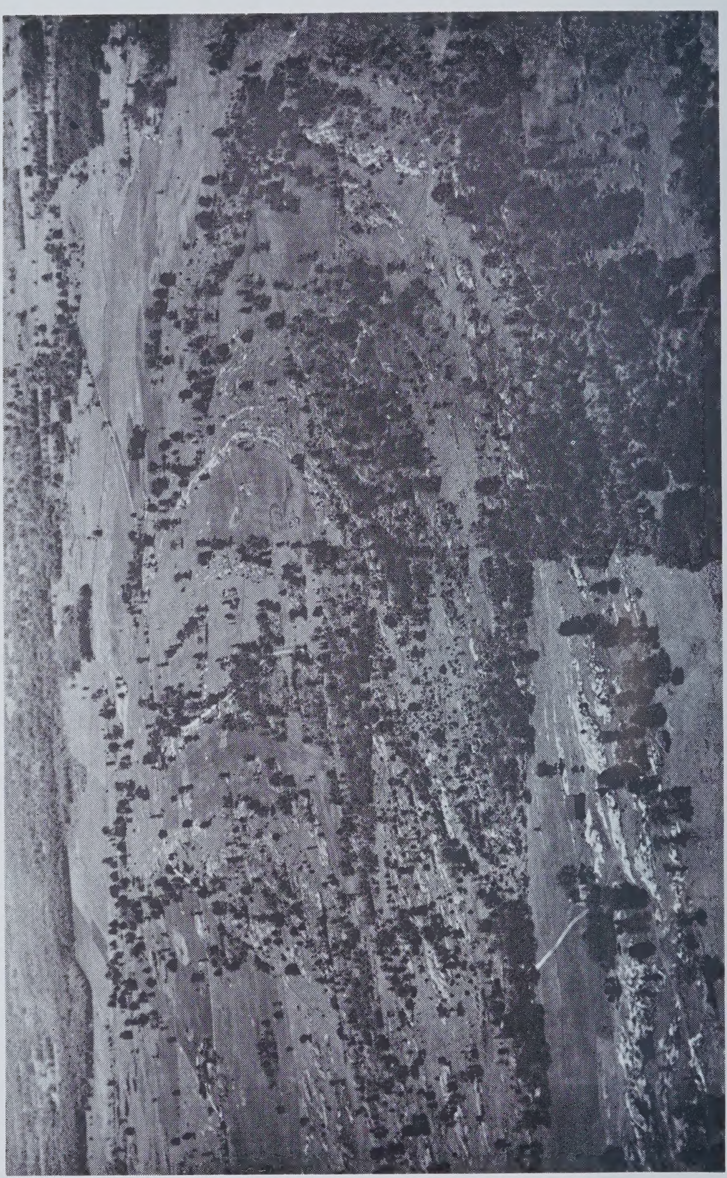


FIGURE 6. Exposed structure in Grenville rocks, as seen toward the southeast from above Black Lake, Hammond quadrangle.

Photograph by $5 Photo Co.

south. The striae recorded during the present survey, and particularly those in the Brier Hill and Hammond quadrangles, however, do not bear out this conclusion.

In areas where the Potsdam sandstone is exposed at the surface in this region, glacial striations, parabolic tension cracks, and lunar marks of shear cracks are well preserved, and the direction of the ice can be accurately determined (figure 7). Numerous measurements were made of the striation directions adjacent to the river, and it is the present conclusion that the ice which made them did not move up the river valley, but instead, moved across the river in a southerly direction. This is to say, ice which made the striae moved southward from the north side of the river.

If the ice had moved up the river and spread out southward, the striations would show ice direction essentially parallel to the river (southwest) and becoming more southerly to the southward. The ice movement, in this case, would be the result of two components of motion: the south-

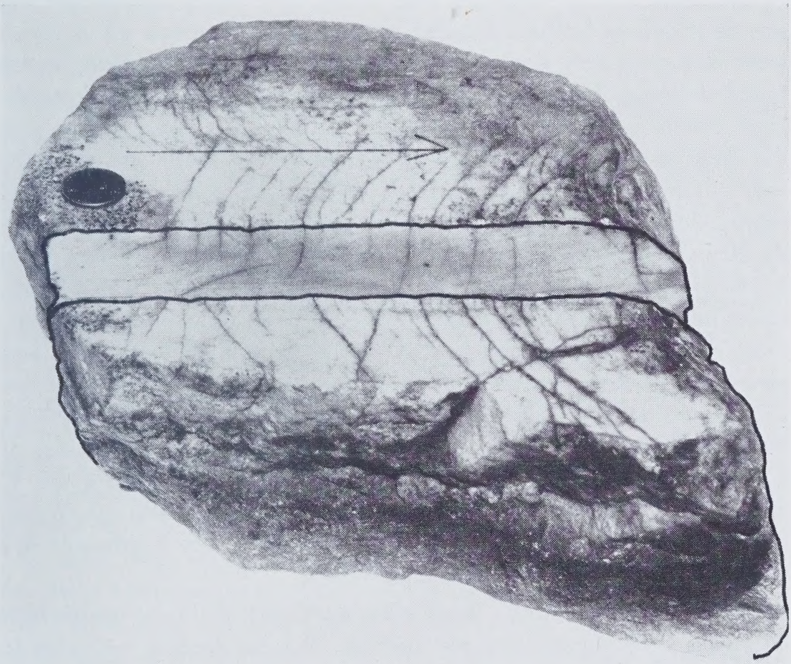


FIGURE 7. Slab of Potsdam Sandstone, with parabolic tension cracks, sawed and pulled apart to show that cracks are vertical or slightly reversed in dip. The arrow is the direction of ice movement; the cracks, therefore, were produced by tension within the rock. Chippewa Bay

westerly movement of the master lobe and the southerly spreading-out-movement due to the weight of the ice. Buddington (1934, p. 48), in a diagram modified from a map by Frank B. Taylor (1924), shows this movement clearly. The fact is, however, that the striations and chatter marks in the vicinities of Morristown and Ogdensburg show that the ice was moving almost due south when it crossed the river, and the direction of movement became more southwesterly as it moved toward the south.

The striations studied and measured during the present investigation in the Brier Hill and Hammond quadrangles are numerous enough to substantiate this conclusion. The most easterly of these measurements is 1 mile south of the city of Ogdensburg. These striations, which trend due south, were measured on the Ogdensburg dolomite in a small excavation that was being dug at the time of this survey. A similar south-trending striation was measured, in a basement excavation, 2 miles west of Ogdensburg. One-half mile west of Morristown, striations were found on the Potsdam, about 100 yards from the river, which show the ice movement to have been S 5°E. Cushing's map of the Ogdensburg area shows five sets of striations between Morristown and Point Comfort, all of which trend approximately due south (Cushing, 1916). The present survey found striations 1 mile east of Point Comfort, 2/10 of a mile from the river trending S 5°W. Two miles due south of the river in this area the striation directions are 10 to 15 degrees west of south, and along the north shore of Black Lake the striations trend 15 to 20 degrees west of south. The evidence that the ice directions was generally southward in the Hammond, Antwerp, and Theresa quadrangles has already been noted by Buddington (1934, pp. 49-51) and Fairchild (1910b, p. 160). Ice, therefore, approached the river from the north in the vicinity of Morristown and Ogdensburg, and crossed the river in a direction that was essentially south. To the west of Morristown, the ice directions are more nearly parallel to the river as the striations show a more southwesterly direction. Fairchild (1910b, p. 160), for example, records directions of S 25°W at Chippewa Bay, S 25-40°W at Alexandria Bay, and S 40-50°W at Clayton. It is believed that the last ice sheet in this area also approached from the north but that its movement spread to the southwest, due possibly to the influence of the river valley.

Glacial striae are rare in the southwestern part of the lowland, where Ordovician limestones form the bedrock. One spectacular exception to this generality occurs in a limestone quarry along N. Y. Highway 179, 2 miles southeast of Chaumont (Clayton quadrangle). Here, dense calcareous varved clays have been stripped to expose an area of about 300 x 500 feet of limestone, which is covered with striae. An older S 20°W set is crossed by a younger S 38°W set. Parallel with this younger set is smeared a layer ½ to 1 inch thick of buff till, grooved S 38°W. Careful inspection shows the surface of this till smear to be water washed. This was obviously done by the waters of the lake before varves were deposited on the till. The till is cemented into a hard brittle rock by the deposition of calcareous material leached from the overlying varved clay, which contains many small concretions in its lower part. Had not this cementation taken place, the till would doubtless have been removed during the stripping operations. The fabric of the stones in this layer of till, which was evidently emplaced by being smeared onto the limestone, shows strong maximum at N 38°E, parallel to the grooving of the till. This occurrence shows that the fabric was produced during the grooving.

III. Black Lake Tableland Subsection

From Chippewa Bay to Ogdensburg and between Black Lake and the St. Lawrence River, flat-lying Paleozoic sediments produce tableland topography. Only patches of till, a few feet thick, are found here and there below lake beds.

IV. The Pine Plains Subsection

The Pine Plains have been described and discussed in detail by former writers, by Fairchild (1912a), in particular. This extensive sand deposit, that extends from Natural Bridge westward to the village of Black River and covers a large portion of the Antwerp quadrangle, has been designated a delta deposit of the Black River. Buddington (1934, pp. 35-37) distinguished two deltas, formed during different lake stages, one the Indian River Delta in the vicinity of Natural Bridge, and the other the Black River Delta farther west. This distinction was made because of the higher elevations in the vicinity of Natural Bridge.

During the present investigation, evidence was sought which would definitely prove or disprove the deltaic origin of the Pine Plains. These efforts, as yet, have failed to accomplish the desired results. Wind-blown sand generally covers the surface of the deposit, so that no openings or outcrops have been found that show the character of the material.

In many areas on the Pine Plains, blowouts reveal large boulders in the sand. Although many deltas contain larger fragments, those in the Pine Plains sands do not seem to fit the pattern of a predominantly sandy delta. It seems possible that this deposit was made when an ice front stood in the area, as Buddington (1934, pp. 35-37) suggests in the Natural Bridge section, and that the sandy material may have come partly from melting ice. It is a fact that the frontal moraines of this region are composed of a sandy till. It is proposed, therefore, that although much of the sand was undoubtedly transported by streams, at least a part of the material composing the plain is of glacial origin. The sediment of the gradually sloping edge of the plains could have been distributed at a later date by wave action.

V. The Southwestern Massive Moraine Subsection

The only massive moraines with bold relief mapped in the western part of the lowland are located along the Black River in the Antwerp and Theresa quadrangles. The extent of these moraines is not known, but they may be a part of a larger morainic system beyond the limits of this survey. Because of the possible significance of these moraines to future investigations, they are designated a separate subsection in spite of their small extent.

The moraines of this subsection range in elevation from 500 to 600 feet in the vicinity of the village of Black River, to over 800 feet in the southeast corner of the Antwerp quadrangle. The structures are composed of sandy, bouldery till with sand content much higher than other tills of the lowland.

VI. Oriented Till Ridges Subsection

Extending from just west of Ogdensburg northeastward 65 miles to the international boundary north of Malone, is a belt of low, elongate ridges of till rising from clay and sand-filled intervening lowlands. This belt averages about 18 miles in width. The mounds of till are elongated parallel with the St. Lawrence River, and trend in a northeast-southwest direction. These ridges have been subdued by waves and currents of the postglacial Champlain Sea. The crests of the hills are commonly capped by coarse stony debris containing marine shells. This deposit was evidently left when the waves winnowed out the fine constituents of the till and washed them into the lowlands. Since the coarser constitutents of the till make up about one fourth of the volume of the till, it is believed that lowering of the tops of the hills by 30 or 40 feet would account for approximately the amount of winnowed till that commonly caps these hills. It is concluded, therefore, that the higher parts of the morainal topography have been lowered a score or more feet by this wave-wash and the intervening lowland aggraded a commensurate amount. Except in a few places near Trout River, this lowering has largely destroyed such details of end moraine topography as might have been present.

VII. Lobate Moraine Subsection

Above the level of the Champlain Sea, end moraine topography is still present on the drift.

Boyden Brook Lobe. In the headwaters of Boyden Brook, just west of Pierrepont on the Canton quadrangle, end morainic topography with a distinct little esker is well preserved at an altitude of about 600 feet.

Raquette River Lobe. South of Nicholville on the Nicholville quadrangle is a large lobe of end morainic topography. It extends about 5 miles to the south to form the dam at the north end of Lake Ozonia, at an altitude of about 1,200 feet. Many kames are present, and a large kame terrace flanks the St. Regis River at Days Mill. This moraine is composed of Malone drift.

Bangor Lobe. On the Malone quadrangle, the re-entrant against the north side of the highlands contains a large patch of end moraine topography, which extends from Bangor 4 miles to the southward to the small hamlet of Skerry.

Salmon River Lobe. This projects southward to Malone, on the Malone quadrangle. Here the morainal topography has been largely buried by postglacial lake delta deposit.

Adirondack Province

The northern fringe of the Adirondack province is included briefly in the current study. It is a gently undulatory upland of 1,000 to 2,000 feet altitude, into which 500 to 600 foot valleys have been cut. The uplands are mantled with relatively thin glacial till, through which the bedrock projects in rounded boss-like masses. The valleys contain kame terraces, which along with the many sand plains of extinct ice-dammed lakes, demonstrate that the ice sheet which overrode the Adirondacks stagnated and melted down *in situ*. The surface physiography might therefore be characterized as consisting of rounded rock bosses (roches moutonnés), thin till patches, sand plains, and kame terraces.

CHAPTER VI

Glacial History

Subdivisions of the Pleistocene Epoch in North America

As long recognized, the standard Pleistocene sequence in North America is as follows:

7. Wisconsin glacial age
6. Sangamon interglacial age
5. Illinoian glacial age
4. Yarmouth interglacial age
3. Kansan glacial age

2. Aftonian interglacial age
1. Nebraskan glacial age

The Wisconsin stage was divided by Leighton (1933) into:

4. Mankato (Valders) age
3. Cary age
2. Tazewell age
1. Iowan age

This classification has become widely used for the drift sheets of the Mississippi Valley region. Application of the same terminology to the Wisconsin drift in eastern North America is still in the formative stage. MacClintock and Apfel (1944) proposed Tazewell and Cary drifts in western New York. Flint (1953) proposed an Iowan-Tazewell complex as the outermost Wisconsin drift, a Cary margin near Middletown, Conn., and Valders (Mankato) in the St. Lawrence and Champlain Valleys. MacClintock (1954) suggested Tazewell at the south, Cary in the middle, and Valders (Mankato) in the north. Denny (1956) suggested Olean and Valley Heads as representing a twofold division of the Wisconsin. Flint (1956) placed the drift in central Connecticut as of Cary age, and gave a table of radiocarbon ages for events of the Great Lakes history, including the last Wisconsin advance of the Valders (formerly called the Mankato) glaciation. Leighton (1957) proposed the following sequence for the Wisconsin:

Valders
Mankato
Cary
Tazewell
Iowan
Farmdale

Probable Correlation of the Glacial Events in the St. Lawrence Lowland

Fairchild (1910) proposed two episodes of glaciation to account for the history of the Thousand Islands region. He hinted at an Illinoian age for the earlier and a Wisconsin age for the later event, with subaerial erosion between. However, there was no stratigraphic evidence upon which to base a chronology. The present study of the drift sequence at Malone and Massena has demonstrated two episodes of glaciation. Ice of the earlier one, the Malone glaciation, moved southwest up the valley and then spread over the Adirondacks, whereas the later, Fort Covington invasion crossed the valley from northwest toward southeast. Between the tills of these two episodes occurs a considerable thickness of lacustrine deposits including sands, gravels, varved clays, and berg-rafted drift. It is proposed that the conditions which produced such radical change in ice movement, with a major lake history between, were important enough to demark at least substages of the Wisconsin.

Fort Covington Substage

It has been generally accepted that during the waning stages of the Wisconsin an ice lobe occupied the Ontario Basin. Opinion differs, however, as to the details of the history of the lobe, i.e., the positions and dates of its advances and recessions. Spencer (1883) proposed such a lobe to dam the glacial Great Lakes. Later, the classic work of Leverett and Taylor (1915) used such an hypothetic lobe to dam Lake Whittlesey, plate 16, Lake Warren, plate 17, Lake Lundy, plate 19, and Lakes Iroquois and Frontenac, plate 21. They proposed minor recessions and readvances of the ice edge to account for opening and closing of lake outlets. The work of Karrow and others, 1961, casts doubt on the validity of these dates.

With the advent of radiocarbon dating, more precise ages and resulting correlation emerged. Two dates for ice-stands of the Ontario lobe become particularly significant. Wood found in sediments reported to be of Lake Warren near Marilla, N. Y., was dated at 9,640 C^{14} years BP (Rubin and Suess, 1955) (W-199) and wood buried by sediments believed to be of Lake Lundy at Castalia, Ohio, was dated at 8,513 C^{14} years BP (Libby, 1951) (C-526). These two dates show that the ice which dammed these two lakes was of Valders age.

Dating of the Fort Covington Episode

No radiocarbon-datable material has yet been found in the Fort Covington till. However, the Champlain Sea sediments, which overlie the till, contain shells which have been variously dated from 10,300 to 11,300 years (Y-233, Y-215, Y-216, Y-217, Gro-1697, Gro-1696) (Preston, and others, 1955; de Vries, 1958; and personal communication). There has been controversy as to the reliability of these dates, since the organisms were living in an environment that contained "dead" carbon. But modern work (Broecker and Orr (1958), and de Vries (1958)) shows that the carbon in the surface waters was so nearly in equilibrium with that in the atmosphere that "dead" carbon affected the age determinations less than 3 per cent. If these dates are trustworthy, then the Champlain Sea was of Two Creeks age. The determination of the age of the basal peat in the St. Germain Bog, near Drummondville, of 9,500 years

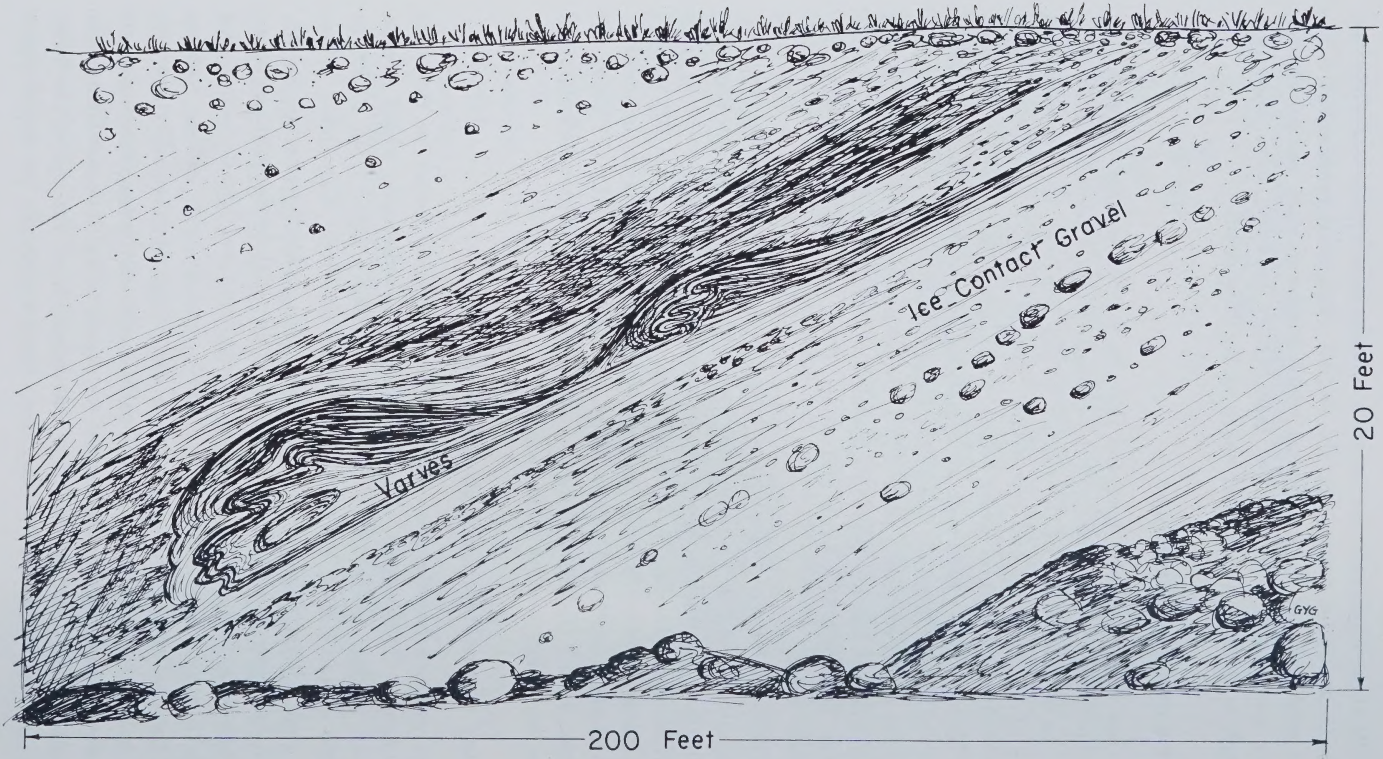

Ice Contact Gravel
Varves
GYG
20 Feet
200 Feet

FIGURE 8. Diagram of gravel pit 2 miles north of Redwood, Alexander Bay quadrangle, showing varved clays slumped into kame gravels

(Terasmae, 1959) shows that this area emerged from the Champlain Sea before this date. This date again confirms the Champlain Sea as of Two Creeks age.

Since the Fort Covington till is overlain by Champlain Sea clays, it is evidently pre-Two Creeks in age. And since the Malone drift came from the northeast, whereas the Fort Covington came from the northwest, this recession and rearrangement of the glacier demarks a substage of the Wisconsin. These various facts point to a Port Huron age for the Fort Covington.

Malone Substage

Malone till is older than Fort Covington till, and came from a different direction in a radically different ice movement. These facts are considered sufficient grounds to assign it to at least a different substage in the glacial sequence. Since no evidence of interglacial weathering has come to light to prove otherwise, and the weathering of its deposits is the same as those of Cary age in regions to the south and southwest, it seems best in the present state of knowledge to assign a Cary age to the Malone episode.

There is, however, one piece of evidence that might suggest an earlier age for the Malone. As will be described later, the deep exposure of the St. Lawrence seaway and power projects reveal that the northeast-southwest hills are composed of a core of Malone till, with Fort Covington till forming a mantle over the hills and draping down under the clays of the lowlands. At the top of the Malone till in the hills, and below Fort Covington till, is a considerable deposit of lacustrine sediment made of sands, gravels, and varved clays. This deposit is the same altitude from exposure to exposure throughout a distance of 25 miles, suggesting that it was all one lake plain.

Dreimanis (1958) finds at Toronto, west of the St. Lawrence area, an interstadial deposit, older than 38,000 C^{14} years, between a lower till with fabric from the northeast and dolomite content suggesting the St. Lawrence Valley, and overlying till with fabric from north-northeast and a low dolomite content. He proposes that the till older than 38,000 years is very early Wisconsin, and that the younger till is "Main Wisconsin"; Gadd (1953) finds at Drummondville to the northeast of the area of this study an interstadial peat deposit older than 38,000 C^{14} years, but of climate colder than that of the typical Sangamon. These two occurrences of terrestrial vegetation early in the Wisconsin open the possibility of an episode of fluvial erosion. If this had dissected the Malone drift, this drift should be correlated with Dreimanis' "Early Wisconsin." No evidence is at hand to confirm the idea.

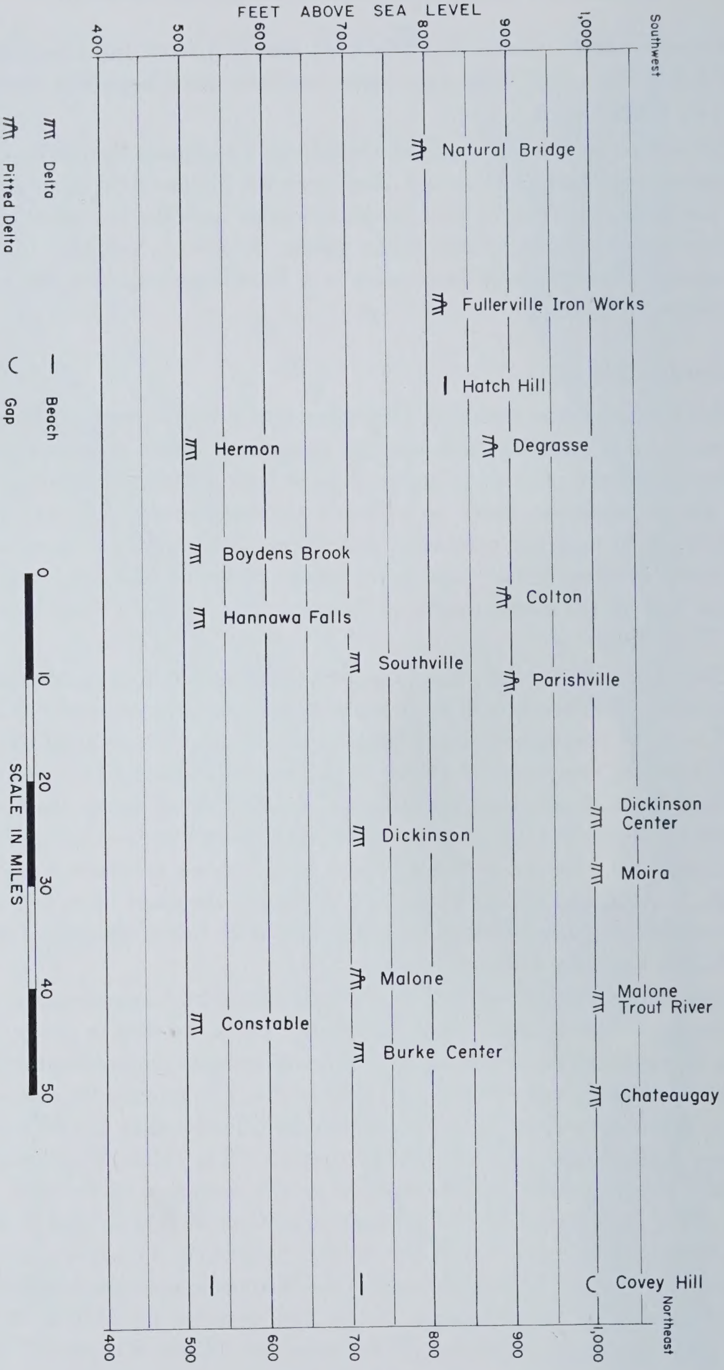


FIGURE 9. East-west profile of deltas

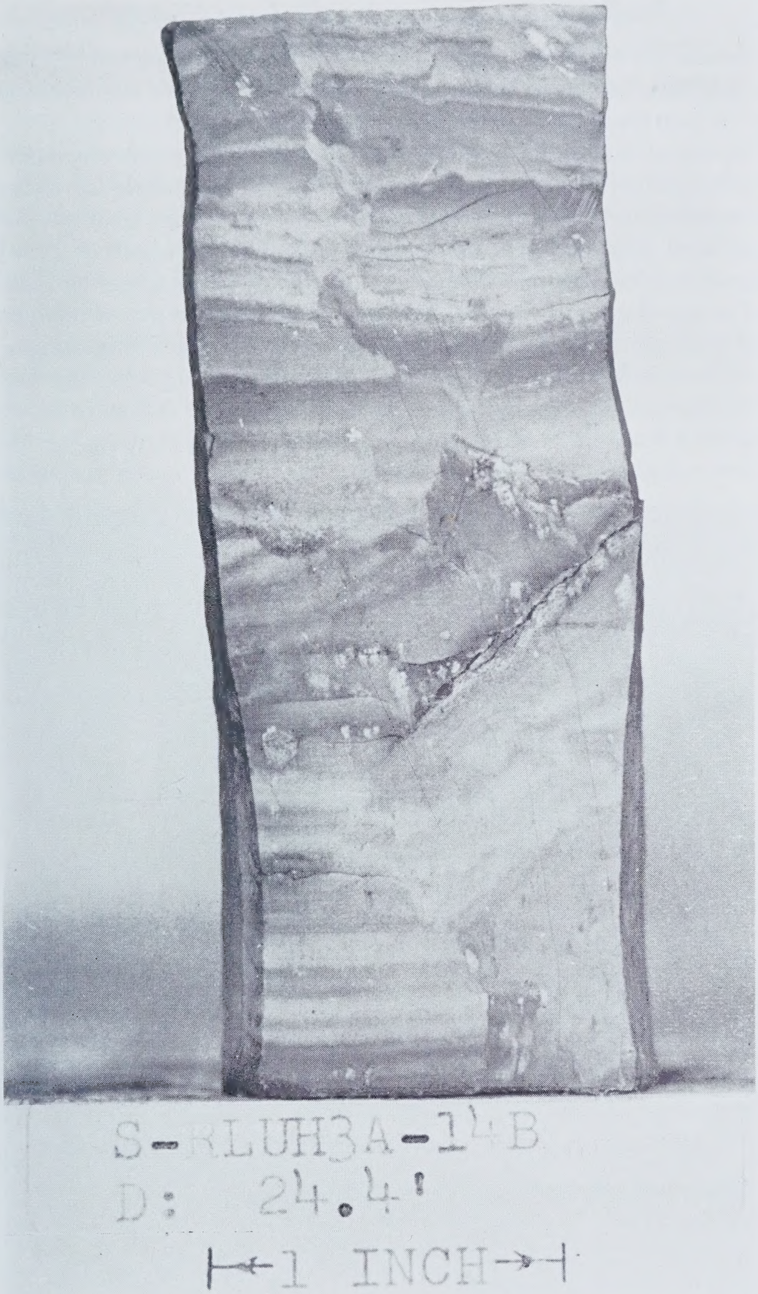

S-RLUH3A-14B
D: 24.4'
1 INCH

Figure 10*a*. Fragmented varved sediments cut from core sample, Richards Landing dike hole No. 3A

Probable Correlations of the Lake History

Malone ice advanced into a lake, as shown by masses of contorted varved clays contained in the lower Malone till and by the layers of varved lake clays between the lower and the upper Malone till.

The upper Malone till is overlain by lake sediments containing extensive berg-rafted deposits. This latter shows that the Malone ice waned by calving into a major lake (figure 8). Fort Covington till overlies these latter lake sediments, as is well displayed in the extensive seaway excavations. The advance of the Fort Covington ice doubtless overrode and largely destroyed beaches and other shore line features of this pre-Fort Covington lake. However, shore lines south of the Fort Covington Moraine may be remnants of such beaches now standing below the level of the Covey Hill Gap, but above the marine beaches and more deeply weathered than Fort Covington drift. Also, it is noted that many of the deltas at intermediate levels are pitted by the melting out of buried ice

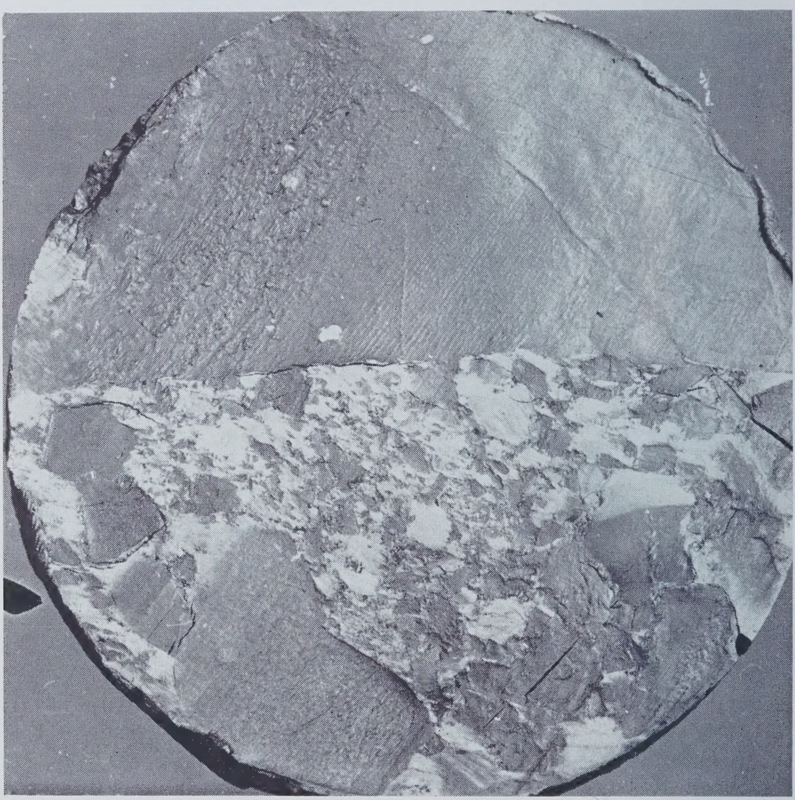


FIGURE 10*b*. Fractured material against massive material at side of a crack filled with broken varves, Richards Landing

blocks. The Malone Delta was pitted by Fort Covington ice blocks, but the others seem to be associated with an older event. With the exception of the Malone Delta, the pitted deltas rise in succession toward the northeast, whereas the Fort Covington and post-Fort Covington features are nearly horizontal. This suggests a rise toward the northeast in pre-Fort Covington and toward the north in post-Fort Covington time (figure 9).

The Fort Covington Moraine impinges against and rises up on Covey Hill high enough to show that its ice dammed a third lake that overflowed at the Covey Gap. Beaches and deltas of this lake are now at 1,000 feet, which is 480 feet above the highest marine shore on the north slope of Covey Hill.

A fourth deposit of varved lake clays is spread across the Fort Covington till practically universally over the St. Lawrence Lowland. They are seen in most of the excavations for the seaway and power projects and in innumerable test drill holes. The beaches of this post-Fort Covington lake occur at about 710 feet altitude (180 feet above the marine shore line), and correspond to the beaches of the Fort Ann stage in the Champlain Valley. The sequence of lakes then is:

1. Pre-Malone
2. Mid-Malone
3. Malone recession
4. Fort Covington
5. Fort Ann
6. Gilbert Gulf-Champlain Sea

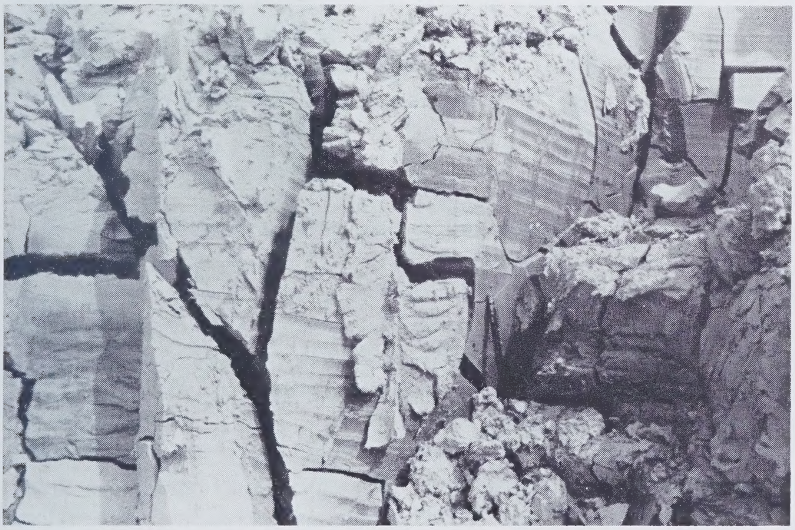


FIGURE 11. Drying and cracking of varved clay. East end of Grass River lock excavation

This discussion of lakes has not considered the date and stratigraphic position of Lake Iroquois. After field work for this report was completed, Karrow, Clark, and Terasmae, 1961, have shown that Lake Iroquois was of Port Huron (Fort Covington) age and formed during the recession of this glaciation from the Ontario basin in early Two Creeks time and before ice had melted out of the lower St. Lawrence Lowland. Consequently Lake Fort Ann may well be a phase of Lake Iroquois in the Middle St. Lawrence and Champlain Lowlands.

Lastly, with the unblocking of the lower St. Lawrence Valley, the lake drained to a low sea level which then rose and invaded the area to produce the Champlain Sea and the Gilbert Gulf. Three types of evidence show this emergence between Fort Ann Lake and the Champlain Sea:

1. Commonly fossiliferous marine clays and/or gravel lie on varved sediments, but other exposures or drill records show the marine beds to lie directly on till in what is evidently an unconformable relationship.

2. In many places, sand and gravel intervene between the varved clays and the overlying marine clay. Likewise, there is gradation upward from gravel to sand to clay in the marine sediments, suggesting a gradual deepening of the marine water.

3. The upper foot of the varved clay below marine clay has a brecciated structure showing that it was desiccated, fractured, and then welded together (figure 10b). The fragments of the varved clay are an inch or two across. This structure is seen best when drying brings out the contrast between more and less silty layers of the varves. A day or two of drying usually brings out the structure well enough to photograph. It seems obvious that this structure would not develop while the clay was situated at the bottom of a 500-foot deep lake, and so demonstrates a period of emergence.

Origin of the Fractured Varved Clay

Lake Fort Ann, in which varves were deposited, was dammed by ice still in the lower St. Lawrence Valley, and drained down the Hudson Valley into the ocean, still at a Pleistocene low sea level.

The ice which occupied the lower St. Lawrence Valley waned enough for the lake to be drained. The hypothesis is proposed that, when this draining occurred, sea level was still low enough that the floor of the lake stood for a time above water.

If this had been the case, fluvial erosion might have affected the surface of the varved sediments by removing them in places, as from tops of low hills of till, and by cutting shallow valleys into them. When the varved sediments were exposed to the air they dried, shrank, and cracked open (figure 11). It is postulated that small fragments of dry,

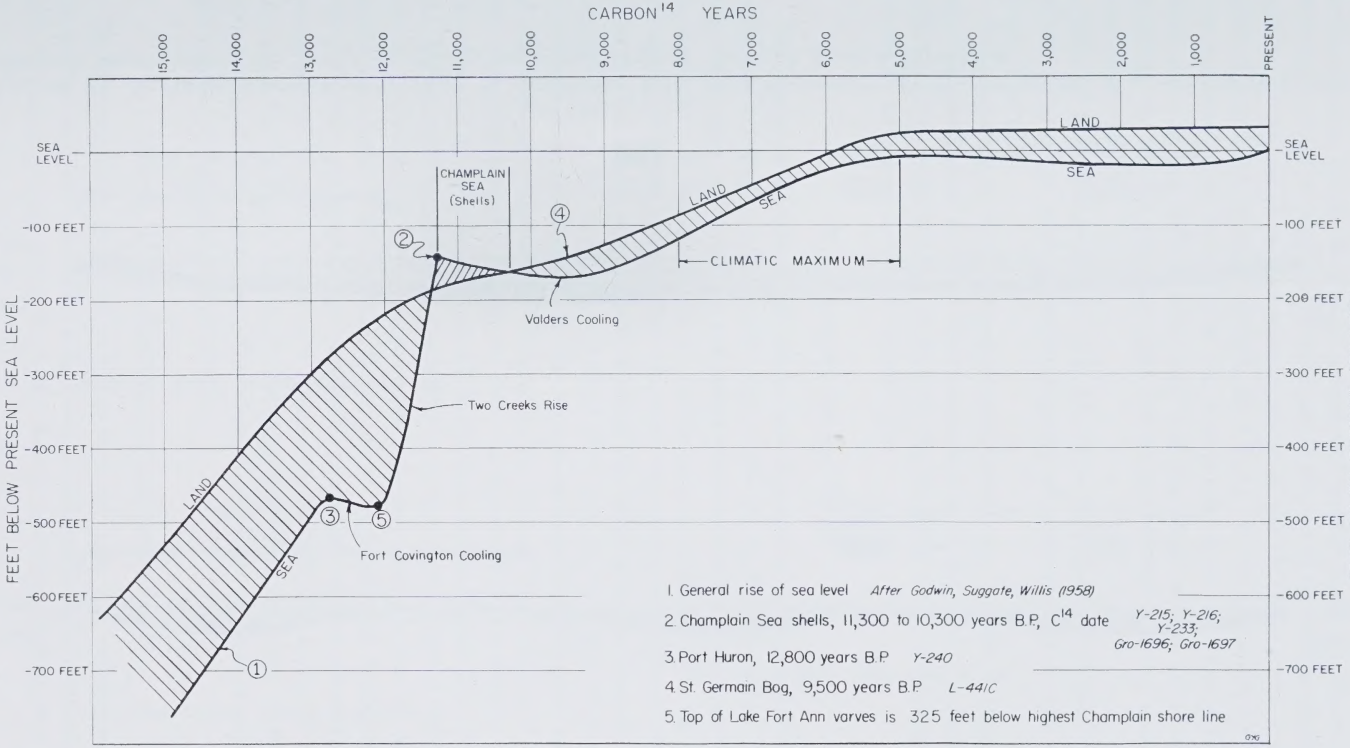


FIGURE 12. Rise of land and sea at the end of the Pleistocene in the St. Lawrence Valley

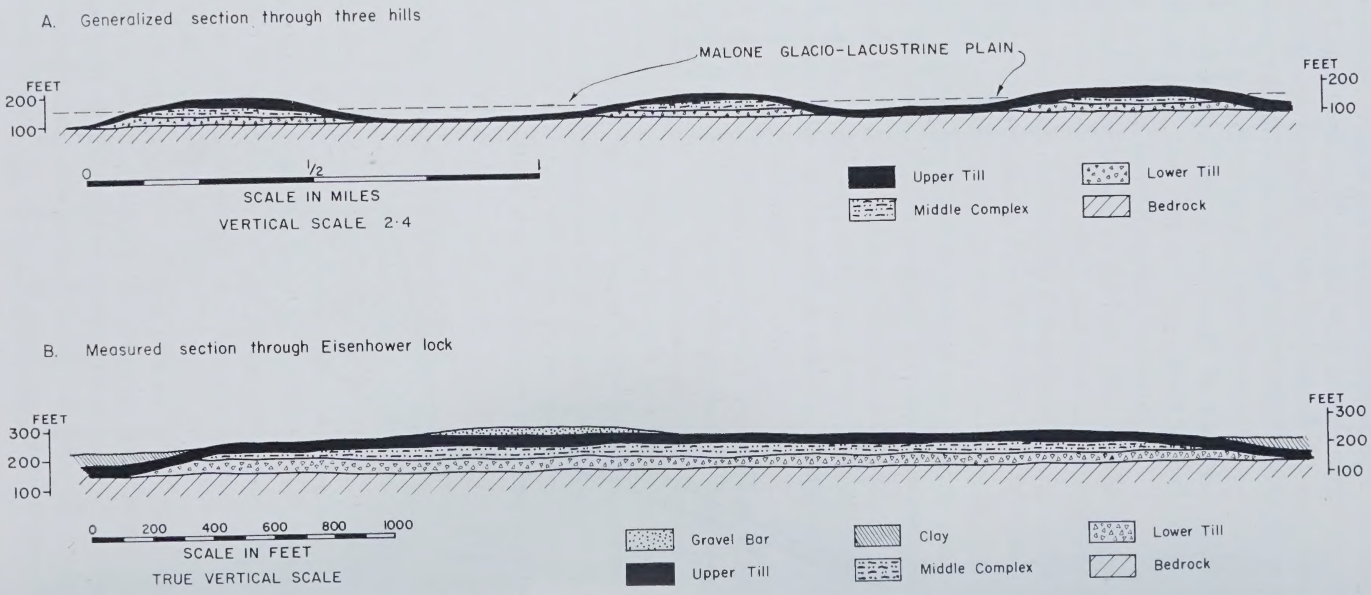

A. Generalized section through three hills
MALONE GLACIO-LACUSTRINE PLAIN
FEET
200
100
FEET
200
100
0
1/2
1
SCALE IN MILES
VERTICAL SCALE 2·4
Upper Till
Lower Till
Middle Complex
Bedrock
B. Measured section through Eisenhower lock
FEET
300
200
100
FEET
300
200
100
0
200
400
600
800
1000
SCALE IN FEET
TRUE VERTICAL SCALE
Gravel Bar
Clay
Lower Till
Upper Till
Middle Complex
Bedrock

Figure 14. Northwest-southwest sections of the major hills near Massena: (a) Upper profile is generalized section through three hills; (b) lower profile is measured section through Eisenhower lock.

varved clay fell or washed into these cracks to accumulate as a mass of broken pieces, which later were wetted and welded together. Masses of this material are seen in many exposures at the top of varved clays below marine sediments. It is also seen in many of the test hole cores at the same stratigraphic horizon (depth, 24.4 feet). Views of the top of the core extracted from hole RLUH No. 4 at depth of 50 feet (figure 10a) show it to be one half massive clay and the other half to be broken material, as though the core was taken just at the wall of such a postulated crack.

Piles of broken fragments might also have accumulated at the bases of any steep slope, such as undercut banks of small streams or any dry slope (figure 11).

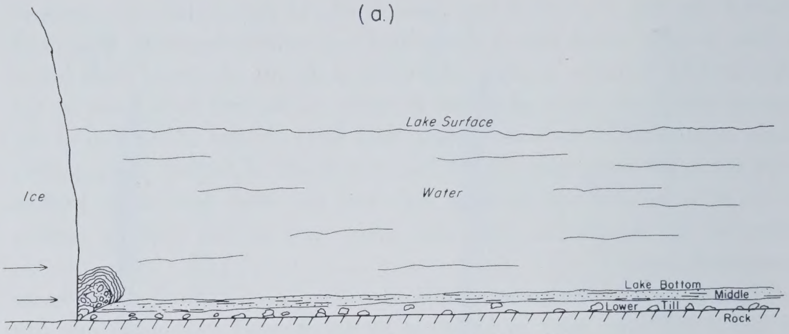
If the hypothesis of drying and cracking of the clay is valid, a diagram may be constructed to show how isostatic rise of the land "jockeyed" with eustatic rise of the sea to produce the emergence and submergence of the St. Lawrence Lowland (figure 12).

Topography of the Drift

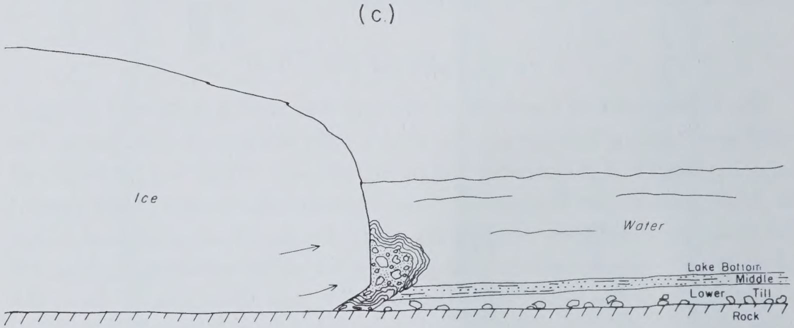
The topography of the drift of the area has such a striking northeast-southwest orientation (figure 13) that it calls for special discussion. The huge exposures of the seaway and power project, which will be described in detail later in the discussion of the Massena quadrangle, have opened for study cross sections through six of the big northeast-southwest ridges of drift. Till-fabric studies have allowed the differentiation between till emplaced from the northeast (Malone till), and till emplaced from the northwest (Fort Covington). In this way, it has been found that the cores of the hills are composed of Malone drift, whereas the surfaces of the hills are composed of a blanket of Fort Covington till which drapes over the tops and down to lie on bedrock in the depressions (figure 14). Since the Malone drift is made of two members, an upper and a lower Malone, which are separated by horizontal lake beds and overlain also by horizontal lake beds, it follows that the ridges are certainly not drumlins or "drumlinized topography" as previously proposed, but are phenomena produced by Fort Covington ice. Since they lie at right angles to this ice advance, they are like giant undulations following each other in roughly rhythmical succession. Three hypotheses come to mind to explain the origin of these great undulations.

Origin of the Northeast-Southwest Hills

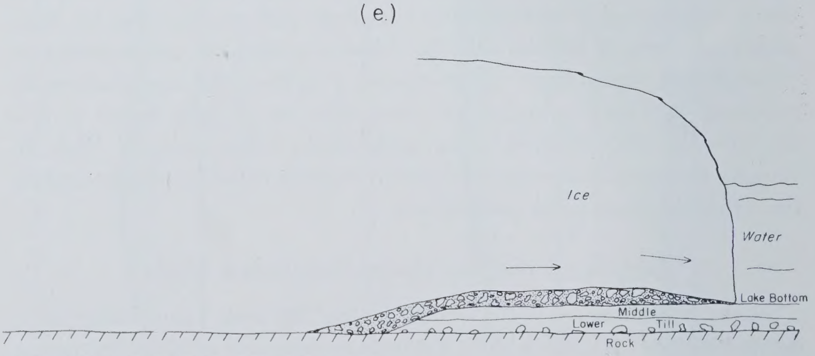
At the beginning of Fort Covington time the area was submerged in an ice-dammed lake which had a flat bottom composed of glacio-lacustrine till, silt, sand, gravel, and varved clay, which had been deposited as the


(a.)
Lake Surface
Ice
Water
Lake Bottom
Middle
Lower
Till
Rock

FORT COVINGTON ICE — GOUGES INTO THE LAKE BOTTOM


(c.)
Ice
Water
Lake Bottom
Middle
Lower
Till
Rock

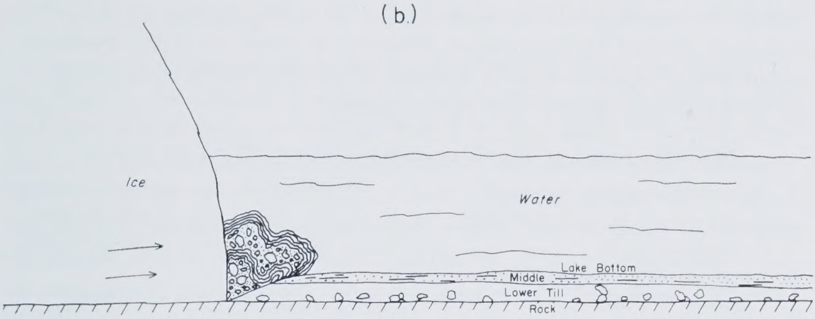
IT BEGINS TO OVERRIDE THE MASS


(e.)
Ice
Water
Lake Bottom
Middle
Lower
Till
Rock

IT FINISHES SMEARING OUT THE MASS

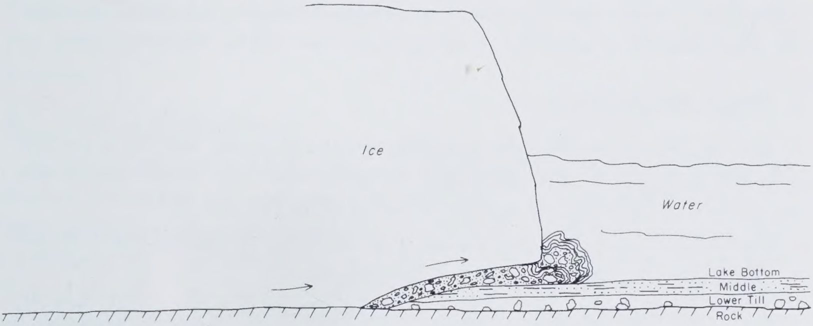
FIGURE 15. Diagrams suggesting how Fort Covington

(b.)


Ice
Water
Lake Bottom
Middle
Lower Till
Rock

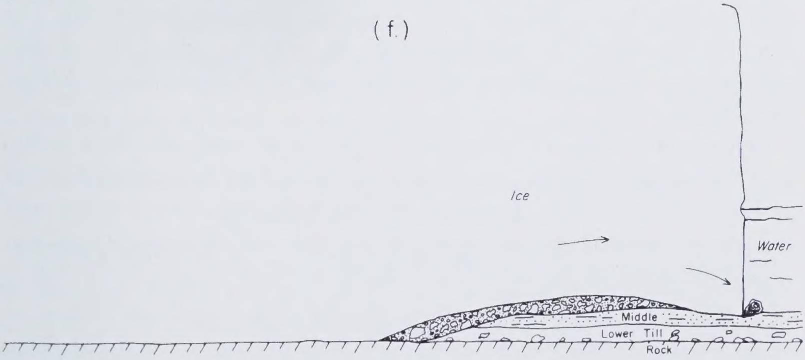
IT PILES UP A MASS OF DEBRIS AT ITS FRONT

(d.)


Ice
Water
Lake Bottom
Middle
Lower Till
Rock

IT CONTINUES TO OVERRIDE THE MASS AND SMEAR IT OUT AS TILL

(f.)


Ice
Water
Middle
Lower Till
Rock

IT BEGINS TO DIG INTO LAKE BOTTOM AGAIN TO START THE NEXT DEPRESSION

Glacier might have made the "giant undulations"

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Malone ice waned while standing in this lake. The flatness of this lake bottom is attested by the present altitudes of remnants of this material as exposed at places through a distance of 31 miles in the excavations of the St. Lawrence seaway and power project:

Cross Sections of the Excavations From West to East*

1.	Sparrowhawk Point, rim dike	230-240 ft.	(top of Malone drift)
2.	Sparrowhawk Point, inland side	250 ft.	(top of Malone drift)
3.	Point-three-Points	240-250 ft.	(top of Malone drift)
4.	Canal through Long Sault Island— ranges 150 to 180	232 ft.	(lake sediments)
5.	Canal, mainland— ranges 207 to 285	210-220 ft.	(top of Malone drift)
6.	Cut "F"	212 ft.	(lake sediments)
7.	Massena power canal intake	230 ft.	(lake sediments)
8.	Eisenhower lock	230 ft.	(lake sediments)
9.	Canal, Eisenhower lock to Grass River lock— ranges 427 to 505	176-220 ft.	(top of Malone drift)
10.	Grass River lock	210 ft.	(lake sediments)

I. First Hypothesis

The rigid front of the advancing Fort Covington ice may have plowed into the material of the lake floor to make a broad gentle depression 20 to 30 feet deep and a couple of miles wide (figure 16).

It plowed up and pushed forward a pile or mass of material at its front.

This pile gradually got bigger and heavier.

When the mass of material got big enough and heavy enough and the friction large enough, the oncoming ice found it easier to shear up and ride over the mass. When the ice had pushed forward about a mile, the pile had become large enough to start the overriding.

Since the mass was still soft and "gooey," the ice spread it out and smeared it on top of the next portion of lake bottom material. This was the Fort Covington till with northwest till fabric on top of the middle till complex, with northeast till fabric, but with the same lithologic composition.

Having thus disposed of the pile of plowed-up material, the ice-edge was free to dig into the lake bottom again and to gouge out the next gentle depression. The somewhat rhythmic succession of gouging and smearing produced the undulating topography of till-capped northeast-southwest ridges rising 50-100 feet above mile-wide lowlands, in what is obviously a rhythmic pattern of topography. This hypothesis allows for many variations in detail, as found in the field from exposure to exposure. Some low areas contain Fort Covington till, whereas others do not.

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* Total distance, 31.1 miles (ranges are 100 feet apart).

II. Second Hypothesis

The second hypothesis is the common explanation of glacial deposition, i.e., that the ice picked up a load of fragmental material from its bed and carried it along in its viscous basal flow. Deposition occurred where the ice became overloaded or motion ceased, and melting finally liberated the drift. In the case of the St. Lawrence Lowland ridges, this type of erosion and deposition would have had to be rhythmic, with a wavelength of roughly a mile, to produce the topography. It may be postulated that the magnitude and viscosity of an ice sheet might have been just right to have produced this effect. The hills and depressions might be likened unto giant current ripples made by excavation and deposition at the base of a thick, very viscous, slowly flowing mass. It is more than coincident that the southeast slope of the hills is commonly a little steeper than the northwest side. If this has significance, it creates a likeness to current ripples. It is not, however, compatible with the first hypothesis of origin. The great viscosity of the ice would make most unlikely waves such as in water.

III. Third Hypothesis

As suggested earlier (figure 12), if there had been an episode of fluvial erosion following the recession of the Malone ice and draining of the lake, valleys might have been cut into the Malone drift plain, and Fort Covington ice might have overridden the hills and valleys to modify them somewhat and to have deposited a blanket of till on them. There is, however, no suggestion of fluvial terrain in the distribution of the hills and depressions as they are now seen. Another possibility seems to be that the pre-Fort Covington cutting might have been accomplished by outlet waters from the Ontario basin surging across the lake plain to excavate channels with a sort of an anastomosing pattern. Fort Covington ice could then have modified them to look like what we have today. Facts from other areas may elucidate this problem.

In the present state of knowledge, the first hypothesis seems most compatible with the mass of facts thus far accumulated.

Origin of North-Northwest to South-Southeast Elements of Topography

Crossing the northeast-southwest drift hills and depressions, which are the dominant features of the terrain and might be designated for convenience as the "first order" hills and depressions, are features oriented north-northwest—south-southeast almost at right angles to the larger features (figure 16). These latter might be designated as "second order" features.

Hills

Superimposed on the main northeast-southwest hills are many small drumlins which are oriented in north-northwest—south-southeast directions. Their northwest till fabric shows them to be made of Fort Covington till. They are commonly found in groups of three or four, lying side by side across a major hill.

A significant process of glaciation, hitherto unrecognized, is exposed to study in the excavation for the north abutment of the Long Sault Dam. This exposure was demonstrated to a large group of glacial geologists, "The Friends of the Pleistocene," by John N. Harris, Director of the Soils Laboratory of the engineers for the New York State Power Authority. At the time of this visit, in May 1957, the excavation had been cut into the west end of Barnhart Island down through drift, laying bare an expanse of bedrock about a hundred feet square. The excavation opened for study drift at the southern end of a small low drumlin. As seen on the topographic map, made before construction activity had destroyed the drumlin, it was about 300 feet long, 100 feet wide, and 10 to 15 feet high; a bigger drumlin about 600 feet to the east is 1,000 feet long and 40 to 50 feet high. The excavation is into drift about 75 feet thick, underlying part of a drumlin field. The distribution of drift is of interest to show what went on under a drumlin during its formation. Detailed study of till fabric at many places around the sides of the excavation, as well as study of striae on the bedrock, shows that:

1. Malone (lower) ice from the northeast cut strong striae in the bedrock N 70° E.

2. On the lower till was deposited the middle till complex, consisting of crudely stratified till, interlayered with varved clay and silt, and stratified sand and gravel. Fabric in the till members is from the northeast, though less pronouncedly so than in the lower till.

3. At the top is upper till (Fort Covington), with fabric from the northwest.

On the bedrock in the center of the excavation the strong N 70° E striae are crossed by short and delicate striae from N 20° W, and the till fabric in a mass of middle complex drift has been reoriented to a northwest trend. The identification of the drift sheets can be made on basis of mineral content of the sand-sized grains, with lower till high in carbonate, middle complex lower in carbonate and quartz, and upper till higher in carbonate, quartz, and feldspar.

These relationships show that the middle complex sediments have been pressed down into a trough-shaped crumpled mass of drift, whose pebbles now have a northwest-southeast fabric orientation. This thrusting must have pushed clear down to the bedrock, and shoved the lower till enough to produce the delicate short northwest striae on bedrock. These phenomena show that Fort Covington ice as it overrode Malone drift must have encountered a soft gooey place here and squashed it down and shoved it forward, and in so doing rearranged its pebbles into a northwest alignment. At one place, as exposed in the cutoff trench, middle complex varves are seen tightly folded with fold axes N 30° E.

Hypothesis of Origin of Hills

Since the exposure under discussion is within a small drumlin field, it would seem to lie within a drumlin-forming environment, i.e., where till accumulates into depositional masses. It is therefore proposed that, where a substrate was encountered which was competent to support the load, a drumlin was built above the "datum" (figure 17a). Where the substrate was incompetent as in a water-saturated soft, "gooey" material, the forces produced downthrusting with forward push and extrusion of material (figure 17b). There was no accumulation above the datum. In humor, it might be called "an upside-down drumlin" with a flat top. With continued push and extrusion of material, a second depression might be started.

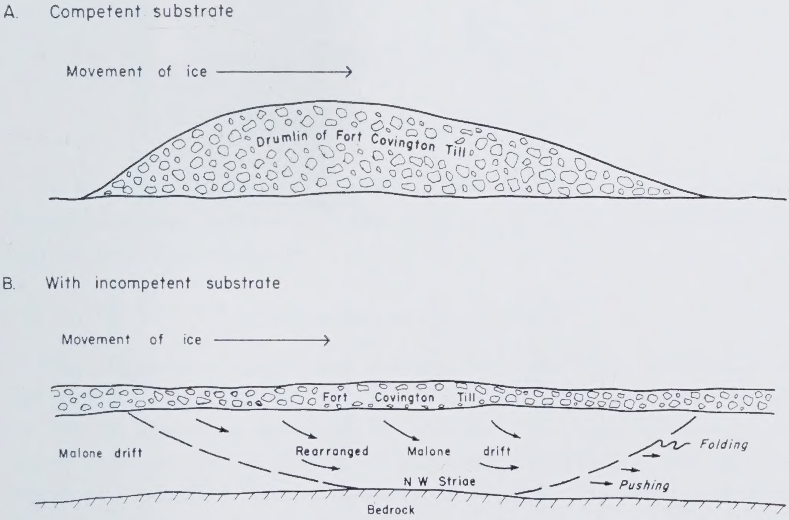
A. Competent substrate
Movement of ice
Drumlin of Fort Covington Till
B. With incompetent substrate
Movement of ice
Fort Covington Till
Malone drift
Rearranged Malone drift
Folding
N W Striae
Pushing
Bedrock

FIGURE 17. Origin of drumlins

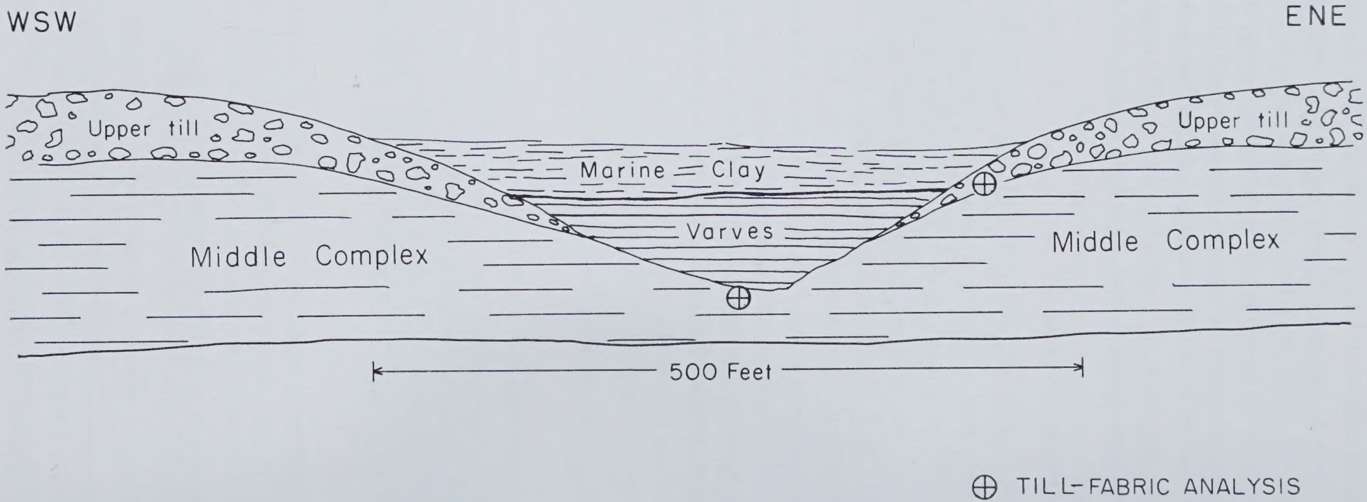
WSW
ENE
Upper till
Upper till
Marine Clay
Varves
Middle Complex
Middle Complex
500 Feet
⊕ TILL-FABRIC ANALYSIS

Figure 18. Section across clay-filled north-northwest to south-southwest trench exposed in the canal excavation, 3 miles north of Massena

Second-Order Depressions

Numerous north-northwest to south-southeast trenches gouged by the Fort Covington ice into Malone drift are now filled with clay, the lower part of which is varved. These varved clays in most cases rest directly on middle complex drift in the bottom of the depressions, but on upper till along the upper parts of the flanks and on the tops of the trenches (figure 18). This occurrence means that Fort Covington till drapes down the flanks of the trenches, but is absent from their bottoms. The fact that Fort Covington till with its north-northwest fabric drapes down the sides of the trenches shows that it was Fort Covington ice that eroded the depression into the middle complex. The absence of Fort Covington till in the bottom suggests that the Fort Covington ice waned while standing in a lake, and that its debris was carried away in icebergs. Numerous ice-rafted stones and rounded masses of till embedded in the varved clays attest to the same condition.

The fact that the large first order depressions commonly contain Fort Covington till in their bottoms, whereas the second order depressions do not, suggests that the former were made during the active advance of the main Fort Covington glaciation from the northwest and were lined with Fort Covington basal till, whereas the latter as well as the drumlins were formed by ice from the north-northwest late in the Fort Covington episode when they could have been liberated from the ice by calving, and thus avoided the deposition of Fort Covington till in their bottoms.

CHAPTER VII

Details by Quadrangles

In the following pages, the details of the glacial history are presented by quadrangles, beginning at the eastern end of the lowland province and progressing westward.

Churubusco Quadrangle

The Churubusco quadrangle adjoins the Chateaugay quadrangle on the east. It covers the upland area which comprises the eastern margin of the St. Lawrence Lowland. Its altitude rises from 700 feet at the north to 2,600 feet at the top of Ellenburg Mountain at the south. It spans the upland divide between waters flowing via Chateaugay River to the St. Lawrence, and those flowing via Chazy River to Lake Champlain. It comprises the northern bulge or bastion of the Adirondack upland projecting northward to Covey Hill, just north of the international border in Canada. The northern part of the area is underlain by flat-lying Potsdam sandstone, whereas the southern part is composed of Precambrian rocks, now eroded into low mountains. Whereas the area is not strictly in the St. Lawrence Lowlands, its glacial history contributes to that of the latter area and so illuminates some of the glacial events of the region that it is included in this report.

Glacial Drift

In the southern part of the quadrangle the Precambrian mountains have a thin and patchy, discontinuous, cover of stony drift with bosses and rounded ledges of bedrock protruding through it. Striae both north and south of Ellenburg Mountain strike NE, showing that the glacier crossed this area from NE to SW (Postel, 1952).

In the northern part of the quadrangle, where horizontal Potsdam sandstone comprises the bedrock, many striae also show ice invasion from the northeast. The drift in this part of the quadrangle exhibits three aspects. On the west side of the Salmon-Chazy River divide, the drift forms a continuous mantle of till with bedrock exposed in only a few places, as on steep little hillsides or the channels of scattered gully bottoms. However, on the east side of this same divide, which passes north-south through Churubusco, the drift is thin and discontinuous, with a great deal of bedrock rubble scattered over the surface, and bedrock ledges and flats making up much of the landscape. Most of the streams flow in riffles and little falls on bare bedrock in valleys only a few feet deep. A dozen scattered patches, each about a square mile in extent, are covered by drift thick enough to control the topography. These patches are commonly occupied by cultivated fields or pastures.

Kames

Scattered over the northern part of the quadrangle are kames in about a dozen places. They have been used for local sources of sand and gravel for construction. Large pits in the kames 2 miles northeast of Churubusco were excavated for gravel during construction of the Rutland Railroad. The most notable kame is the one at Ellenburg Depot that stands as a gently curving ridge 2½ miles long and 100 feet high. It trends northwest at right angles to the striae of the area. Many gravel pits show it to be composed of gravel and sand. The exposure on its western slopes show cobbly gravel, whereas those on the eastern slope are mostly pebbly sand. The top of the ridge is surmounted with a small sharp hill in "kame and kettle" topography. The North Branch Great Chazy River, after traversing a flat mile-wide alluvial-filled basin, cuts through a low part of this ridge at Ellenburg Depot. The ridge evidently ponded the river until it could overflow at the low place and cut its valley. The feature is best explained as an elongate frontal kame, with the sandy phase deposited as ice melted away from a ridge. Ripples in the sand show south-flowing waters along the ice margin. Tests with acid show the gravels of the kames to be calcareous, below a surface zone from which the lime has been leached to depths varying from 6 to 8 feet in different gravel pits and different parts of the same pit. Calcareous pebbles make up about 15 per cent of the stones in the gravel.

"Flat Rocks"

Flat-lying sandstone is exposed in 10 or more roundish areas a half mile to a mile across, with only a bunch of moss here and there, and a few stunted evergreens and blueberry bushes in joint cracks and bedding surfaces. These areas of bare rock are called by the local people "flat rocks." The two largest of these flat rocks lie in the northeast corner of the quadrangle. The northern one is known as Stafford's Rock and is 1½ miles north-south by 1¼ miles east-west at about 780-800 feet in altitude, whereas the southern one, 1 mile north-south by 1¾ miles east-west and 820-880 feet in altitude, is known as Blackman's Rock. Woodworth (1905), following the suggestion of G. K. Gilbert, described these flat rocks as produced when glacial drainage came through the Covey Hill Gap and flowed southeastward along the waning edge of the glacier as it retreated off the Adirondack highland. This suggestion has certain appeal, but the lack of gradient for such proposed flood waters is a serious objection. Recent accurate surveys now place the level of "the Gulf" at the northern end of such a spillway at 810 feet, and the crest of the flat rock southeast of Altona 17 miles away also at 800 to 810 feet. Furthermore, within the Churubusco quadrangle there are quite a number of these flat rock areas, ranging in altitude from about 800 feet in the north to 1,500 feet near Ellenburg Center on the drainage divide. These patches seem to have been washed clean by local drainage along the receding ice edge. The same may well be true of the large areas at the eastern edge of the quadrangle, and those further east on the Mooers quadrangle.

Spillways

Crossing the drainage divide, in the northwestern part of the quadrangle, are four spillways washed bare of drift but containing no stream at present. In fact, the northernmost spillway, 1½ miles north of Clinton Mills, has a few inches of peaty material on its bedrock floor. The altitudes of these spillways are progressively lower from south to north, as follows: 3¼ miles south of Churubusco at 1,305 feet; 2 miles south of Churubusco at 1,290 feet; 1 mile northeast of Churubusco at 1,150 feet; 3 miles northeast of Churubusco at 1,090 feet.

A fifth spillway, 6½ miles northeast of Churubusco and ½ mile north of the northern edge of the Churubusco map, is the Covey Hill spillway at 1,010 feet. Since there is no accumulation of sand and gravel at either end of the spillway, it must have been clear lake water which did the washing rather than sediment-laden glacial melt-water. It would be logical, therefore, to consider these spillways as the temporary overflow channels of relatively small ice-dammed lakes drained to lower levels as the ice edge waned. This hypothesis would account for the horizontal gravel bars on the Chateaugay map at 1,150 feet, 1,100 feet, and 1,080 feet, as well as certain shore line features on the Malone map farther west.

Correlation

Malone drift. Striae and till fabrics show that ice which overrode the quadrangle came from the northeast. Furthermore the calcareous gravels of the kames have been leached 6 to 8 feet, the same as the Malone age kame gravels at Brainardsville, south of Chateaugay, and along Salmon River south of Malone. The drift of the Churubusco quadrangle is therefore correlated with the Malone glaciation of the St. Lawrence Lowland.

Fort Covington drift. In the extreme northeast corner of the quadrangle, two small ridges ¼ mile long and 20 to 30 feet high exhibit bumpy, terminal, moraine topography and are littered with large boulders. These ridges lie along the margin of the Fort Covington drift sheet. This margin, after crossing the northwest corner of Chateaugay quadrangle, looped up over the northern flank of Covey Hill and back south into the United States in the northeast corner of Churubusco quadrangle (figure 19). From here this margin passes due eastward across the northern edge of Mooers quadrangle, thence south-southeast just west of Chazy where younger northwest striae are seen to cross older northeast striae. The row of kames at Ingraham (which has been thought of as an esker) may well be the marginal moraine. In northwest Vermont, the northwest striae suggest that this same movement striated Mount Mansfield, but did not overtop Worcester Mountain where striation is from the northeast. North of this margin, till fabrics are from the northwest; south of it, they are from the northeast. (Appendix I-AA through KK, inclusive.) The fact that the Fort Covington ice did not project farther into the Champlain Lowland shows it to have been a relatively restricted event in the glacial history.

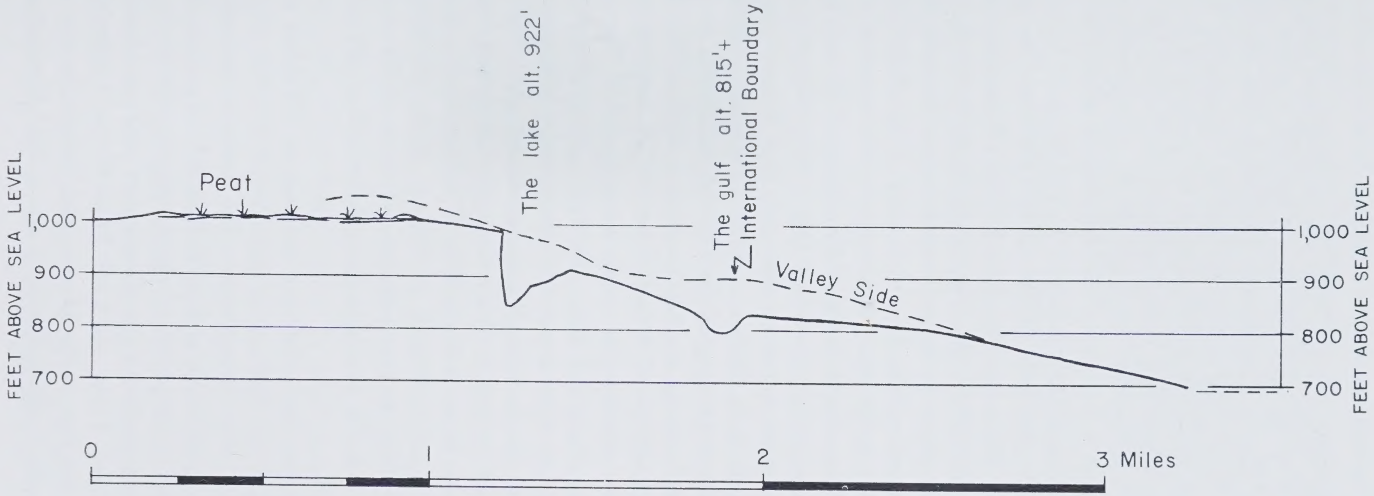
FEET ABOVE SEA LEVEL
1,000
900
800
700
Peat
The lake alt. 922'
The gulf alt. 815'+
International Boundary
Valley Side
FEET ABOVE SEA LEVEL
1,000
900
800
700
0
1
2
3 Miles

FIGURE 20. Longitudinal profile of Covey Hill spillway

Covey Hill

As mentioned earlier, Covey Hill lies in Quebec a mile north of the north boundary of the map. Its glacial history, however, is so closely associated with that of Churubusco quadrangle that discussion of it is included here. Covey Hill is the outstanding topographic feature of the region. It forms the northern terminus of the plateau of the Churubusco area where the Adirondack upland projects northward into Canada. Its altitude of 1,100 feet is 900 feet above the St. Lawrence Lowland, above which it stands as a bastion of the Adirondack Mountains.

A mile southwest of the summit of the hill lies a col ½ mile wide and 1 mile long, with a flat floor at altitude of 1,010 feet. This has long been known as Covey Hill Gap (Woodworth, 1905; Fairchild, 1919; Taylor, 1935) and has been believed to have been a spillway for the Great Lakes-St. Lawrence drainage as the ice receded from the Adirondack Mountains. The east end of the gap is the site of an abandoned waterfall, plunge pool, and steep-walled little canyon. The waterfall was about 63 feet high, i.e., from 985 to 922 feet, the altitude of the lake in the plunge pool. The water in the lake is 70 feet deep at its western end, and shoaling to 35 feet midway toward the eastern end. The "canyon" extends a mile eastward from the lake. Midway, where the vertical walls are about 85 feet high, is a second stagnant pool known locally as "the gulf." The local "authority" reports that he sounded it with an iron weight on a piano wire and measured 70 feet of water. The longitudinal profile of the gap, the lake, and the gulf are shown (figure 20). The waters of this ice age "Niagara" rushed down the steep eastern slope of the divide from 1,000 feet to 820 feet and excavated the gulf and the lake, as cascades sapped the horizontal layers of sandstone.

As mentioned earlier, the Fort Covington marginal moraine drapes over the northern flank of Covey Hill. It is this moraine that determines the course of the East Branch of Outarde River, down the northwest slope of Covey Hill. At this maximum advance of Fort Covington ice, the drainage of the St. Lawrence was ponded and overflowed here at the Covey Gap.

The lake beaches and deltas now standing at 1,000 feet altitude along the north flank of the Adirondack upland were therefore deposited in the lake dammed by Fort Covington ice. The beach in the northwest corner of Churubusco quadrangle at Liberty Pole School and vicinity is one of them. Extensive development of shore features crosses the Chateaugay quadrangle through the town of Chateaugay with sand and gravel deltas on the Chateaugay, Trout, and Little Trout Rivers. Farther west, beaches are seen at 1,000 feet on the Malone, the Nicholville, and the Potsdam quadrangles—all of which therefore are of Fort Covington age.

The water flowing out of the lake and through Covey Gap carried no sediment and made no noticeable deposit at its eastern end. There are two small deposits of pebbly sand resembling beach material at about 800 feet, and another 2 miles to the east at 735 feet. According to Chapman's figure 12 (1937) the upper would be his Coveville shore and the lower, his Fort Ann shore. The evidence, therefore, suggests that the Covey Gap waters flowed down into Lake Vermont at the Coveville stage. The ice no longer stood on Covey Hill at Fort Ann stage, since this lake was confluent to the Malone Delta.

Chateaugay Quadrangle

The Chateaugay quadrangle lies at the eastern end of the St. Lawrence Lowland; in fact, it slopes from an elevation of 2,400 feet in the Precambrian Adirondacks at the south, down to the St. Lawrence Lowland plain of 300 feet elevation at the north. This slope below about 1,500 feet is largely covered with Malone till through which the north-flowing rivers such as Trout, Little Trout, Chateaugay, Marble, and Hinchinbrook have cut their channels. This till is commonly gray-brown to red-brown in color. It is leached 8 feet, 1½ miles southwest of Chateaugay; 6 feet in the new Chateaugay High School excavation; and 6 feet, 1 mile north of Burke Center. The till here shows fabric from the northeast in Malone till (Appendix I-S). A good exposure of the red-brown till is seen in the new cut made where U.S. Route 11 crosses Trout River at the western edge of the map; 20 feet of dense, stony, silty, till is exposed to study. The stones are mostly Potsdam sandstone with small amounts of red shale, some gneisses and limestones, and quite a bit of mixed metamorphic rocks. A leaching test was difficult because of extensive slumping, but it is safe to say leaching has progressed to 8 or 9 feet. The general land surface here is quite flat. The Trout River has cut a ravine about 100 feet deep in the till.

The southern third of the quadrangle is composed of Precambrian rocks littered with boulders and patches of thin till.

An exposure along Trout River Valley, 3½ miles southwest of Burke, shows 19 feet of pebbly beach sand over 50 to 60 feet of silty, dense, brown till, with Potsdam sandstone at the bottom. This shows that Trout River has cut a 60-foot valley through till in post-Iroquois time.

At ½ mile northwest of Earlville, no lime was encountered within a depth of 4½ feet. Chateaugay River has cut a sharp 190-foot ravine through till and 50 feet into Potsdam sandstone. The depth of postglacial erosion is striking.

Kames are scattered here and there within the till area. In the gravel pit near Brainardsville, the gravel is leached 7 feet, where 22 per cent of the material is calcareous. In the kame 1 mile south of Chateaugay, the gravel is leached 8 feet. These depths of leaching suggest that the Malone drift is of Cary age. The large kame and kame terrace area in the valley of the Salmon River in the southwestern corner of the quadrangle is also leached to about 5 feet, showing it to be of the same age.

Chateaugay Channels

Between Chateaugay and the Lower Chateaugay Lake the terrain is crossed by a score or more abandoned channelways. They are generally fairly straight trenches in the drift, 25 to 75 feet deep, 300 to 400 feet across, and floored with a mosaic of boulders, in many places close enough so that it is possible to cross the bottom of the channel by stepping from boulder to boulder. These depressions trend east-west, diagonal to the general northward slope of the land. The channels begin at various altitudes, but none extend below 1,000 feet, i.e., the level of Covey Gap shore line, where they are covered by shore deposits. The channels in places join and part in anastomosing pattern (figure 21), suggesting stagnant ice blocks (see Gravenor and Bayrock, 1956). Fairchild (1919)

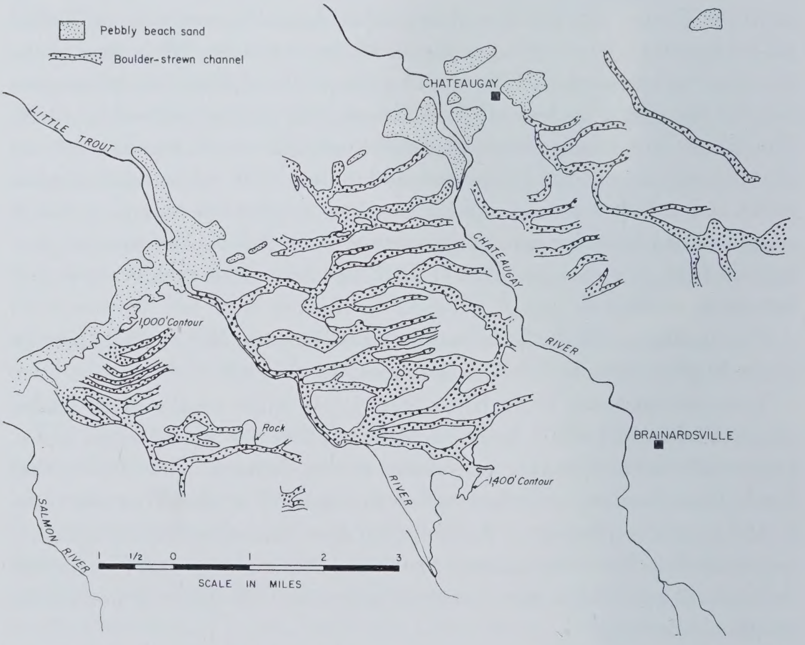
Pebbly beach sand
Boulder-strewn channel
CHATEAUGAY
LITTLE TROUT
CHATEAUGAY
RIVER
1,000' Contour
Rock
RIVER
1,400' Contour
BRAINARDSVILLE
SALMON RIVER
1 1/2 0 1 2 3
SCALE IN MILES

FIGURE 21. Pattern of boulder-strewn channels south and west of Chateaugay; traced from air photos onto the contour map

mapped them on plate 5 as ice-marginal drainage channels. They must have been the work of considerable concentrated flow from ice-dammed lakes, probably in the basin of the present Chateaugay Lakes, the northern end of which was blocked by ice of the waning glacier so as to force the drainage diagonally across the slope of the land. The 7-foot leaching of the gravel at Brainardsville and the till at Chateaugay suggest Cary age for the drift, and hence for the channels.

Channels near the western edge of the map, about 2 miles west of White Church, are associated with kames and the beaches of ice-dammed lakes. The best example is a ridge 20 feet high made of kame gravel in the lower part and in the west end, but of which the middle and upper part are composed of horizontally-bedded clean-washed sharp, pebbly, beach sand. The altitude is 1,100 feet, well above Covey Gap level, so it must have been a kame built into a small ice-dammed lake with outflow on the Churubusco map. The 5 feet of leaching suggests Cary age. Trout River also built a little delta 1¼ mile south-southwest of White Church into a lake, which stood at 1,140 feet and had its spillway at Churubusco.

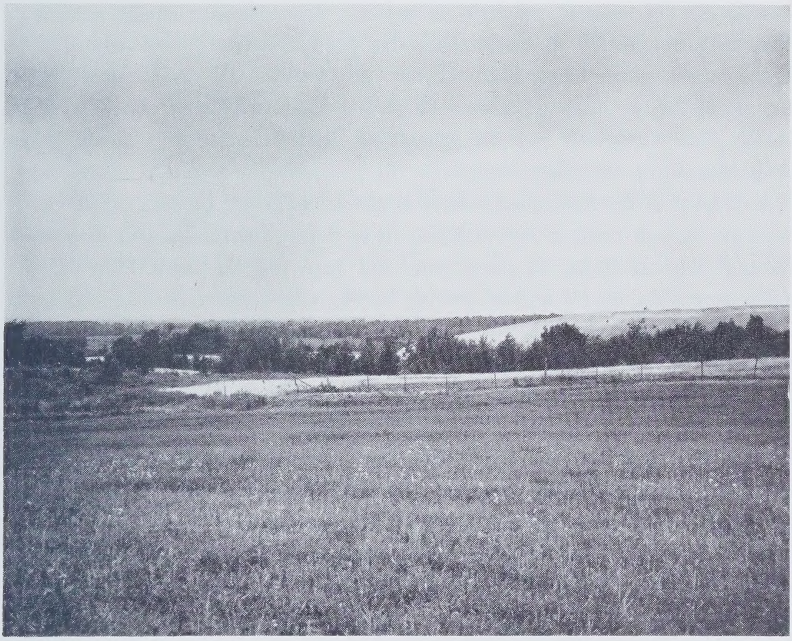

FIGURE 22*a*. Front of the sandy delta of Trout River toward the north. Altitude of top is 1,000 feet; 3 miles east of Malone, Chateaugay quadrangle

Photograph by J. Heller

Shore Lines

Three shore lines cross the quadrangle, as revealed by wave-washed pebbly sand deposits.

The highest shore line now stands at about 1,000 feet above sea level. The surface of the easternmost patch of sand, 3 miles east-northeast of Chateaugay, stands at 1,015 feet. It is about ½ x ½ mile in extent, and has a gravel pit in a shore beach near its southeastern corner. There are patches of sand east, north, south, and west of the center of the village of Chateaugay. The deltaic mass with boulders on the west side of Chateaugay River declines from 1,020 feet at the south to about 940 feet at the north. A continuous sheet of pebbly sand with deltaic fingers protruding northward stretches from Burke westward for 5 miles, almost to the edge of the map (figure 22a). The southern edge of this sandy mass is at 1,000 feet altitude. One-half mile east of the western edge of the map, this sand deposit is seen to lie on red-brown till leached to a depth of about 6 feet. This shore line is assigned to the lake which drained at Covey Gap.

A second and lower pebbly sand shore line is at 720 to 740 feet above sea level. The larger patches of pebbly sand in this range are near Hinchinbrook Brook at Earlsville, near Marble River 1½ miles north of Chateaugay, near Chateaugay River at Crayton Holland, near Adler Brook at Burke Center, and near Little Trout River 1 mile west of Burke Center. About 1½ miles west of Burke Center is a beach ridge 8-10 feet high, with lime crusts on little pebbles at a depth of 3½ feet. A mile west of Burke Center, where Little Trout River crosses the 700-foot contour, it has built a well-defined little delta with a flat top and well-formed frontal slope. A farm road cut into the northern face of this delta exposes 8 to 10 feet of pebbly sand, with foreset bedding dipping northward parallel with the frontal slope of the delta. No lime was found, so it is concluded that the delta is built of noncalcareous material from the Adirondacks to the south and/or from the leached upper part of Cary till, and a sandy deposit at the western edge of the map which is part of the large Malone Delta. This shore line at 720 foot altitude correlates with the Fort Ann stage of Lake Vermont (Chapman, 1937), in the Champlain Valley 12 miles to the east.

The third and lowest group of shore line deposits is at 520 feet altitude near Cooks Mill on the Chateaugay River, near Sun and near Coveytown Corners. These deposits are very commonly gravel bars and beaches. This shore line correlates with the marine shore at 525 feet on the north slope of Covey Hill, 10 miles to the northeast (Goldthwait, 1913). The lane north of this shore line is strewn with gravel beach ridges, with wave-washed till and gravel between. These bars and storm beaches were made by waves of the Champlain Sea as the land gradually emerged. Fossils have not been seen within the Chateaugay quadrangle, but they are abundant a few miles to the west on the Malone sheet and to the north on the Huntington, Quebec, sheet.

Fort Covington Drift

The southern border of the Fort Covington drift sheet crosses the northwest corner of the quadrangle. A mile north of Burke Center, a gentle northeast-southwest swell in the topography controls the direction of Alder Brook and Allen Brook. This low ridge exhibits subdued terminal moraine topography. Till fabric (Appendix I-T) shows it to be Fort Covington. A test pit on the crest of the low ridge, a mile due north of Burke Center, showed the material to be stony, bouldery till. No leaching test could be made because no calcareous material was reached in the test pit and boring. However, near the western end 2 miles northwest of Burke Center, and near the eastern end 2 miles northeast of Burke Center, the soil auger reached calcareous buff till at 40 inches. If this ridge be the subdued moraine of the Fort Covington drift, it accounts for the right angle turns of Alder Brook and Hinchinbrook Brook. Its prolongation to the southwest correlates with the moraine at Malone. The line is therefore drawn through Cooks Mill and the Alder Brook Valley to Malone. At about this boundary occurs a thick deposit of water-laid drift. It is seen in a high-cut bank of the Chateaugay River ¼ mile north of Cooks Mill, about 3 miles northwest of Chateaugay. The 75-foot bluff is composed of stratified silt, containing lots of striated glacial stones. Some of the thinner stratifications are of smooth clay resembling winter layers of varves. No shells are present. It could best be explained as a deposit formed where the ice edge stood in lake waters, i.e., glaciolacustrine till.

Malone Quadrangle

The Malone quadrangle lies due west of the Chateaugay and, like it, comprises an area on the north flank of the Adirondack Plateau. It slopes from the Precambrian upland at 1,600 foot elevation on the south to the St. Lawrence Lowland at 200 feet on the north. The slope is drained northward through Little Salmon River, Deer Creek, Salmon River, Trout River, and Little Trout River. The Salmon and Trout Rivers are sizeable streams, and have cut 100 feet or so into the drift. The southern part of the quadrangle has extensive areas of Precambrian rock, thinly mantled with till and a few scattered kames. The central part is a gently sloping till plain dissected by shallow little valleys, except for the larger ones mentioned above. This till plain is partly mantled with patches of pebbly beach sand associated with the three ancient shore lines described on the Chateaugay quadrangle—i.e., a shore at about 1,000 feet elevation, Fort Ann stage of Lake Vermont at 700 to 740 feet elevation, and Champlain Sea at 500 to 520 feet elevation. The Salmon and Trout Rivers, particularly, accumulated considerable deltaic deposits of silt and pebbly sand where they cross these shore lines. These sandy deposits have been subsequently trenched by the rivers that built them. In places, as at Malone, the trenching has not resurrected the former valley and the stream is superimposed on the hard rock of the former valley wall, resulting in rapids and falls.

The kame terraces that occupy Salmon River Valley from Malone southeastward to Owls Head, in the Loon Lake quadrangle, have been leached to a depth of 6 to 8 feet as shown at the Perone pit 2 miles southeast of Malone, in Todds pit, 1 mile northeast of Chasm Falls on Chateaugay quadrangle, and in the highway excavation 1 mile southeast of Chasm Falls. This depth of leaching and the association with the red-brown till, to be discussed later, suggests a Cary age for this drift. Many of the lower gravel hills are draped with silts and varved clays deposited in an ice-dammed lake, suggesting that lake waters flooded the lower part following the waning of the Cary ice but before the Salmon River could carry enough load to build a delta. The northern part of the quadrangle is made of low northeast-southwest morainal ridges of till, washed and subdued by wave erosion in the Champlain Sea, standing slightly above flat-floored lowlands filled with marine silt and clay and a capping of a few feet of marine sand.

Two Tills Superimposed

At the valley of Trout Creek, 2½ miles northeast of Malone, the borrow pit for a new bridge constructed in 1956 and 1957 exposed a vertical section of till about 30 feet high which showed the following:

Pebbly sand, 5 feet
Varved silt and clay, 1-3 feet
Buff calcareous till, 10 feet
Sand and silt calcareous, 2 feet
Red-brown till calcareous, 2 feet
Floor of pit

The red-brown till (Appendix I-B) has fabric with strong northeast maximum, whereas the buff till has fabric with strong northwest fabric maximum. These two tills are therefore Malone and Fort Covington, respectively.

Southeastward from this exposure, the red-brown Malone till is found along the steep slope of Trout River Valley. Its fabric orientation diagram shows a northeast maximum (Appendix I-C). It is leached to the depths of 8 to 11 feet. A good exposure of the red-brown till in the excavation for Webster Avenue in Malone was selected as the type locality of Malone till. It shows a strong northeast maximum in till fabric (Appendix I-A).

Study of the gray-buff drift $\frac{1}{4}$ mile northwest of the bridge borrow pit shows emplacement from the northwest (Appendix I-O). One mile northeast of Constable, it trends about N 50° W. Three miles north-northeast of North Bangor (Appendix N) along east branch of Deer Creek, gray till has fabric N 50° W. These various phenomena indicate two episodes of glaciation in the Malone area; the first bringing red-brown drift from the northeast, and the second bringing gray drift from the north and northwest. The gray drift forms the northeast-southwest mounds of till in the northern part of the quadrangle. It lies as a till sheet near Bangor Station, North Bangor, Bangor, and West Bangor and forms the strong terminal moraine topography south of the Bangors to Dickinson and Dickinson Center. At East Dickinson, the striae bear N 25° W. A dashed line is drawn on the map to show approximately the southern boundary of the gray-buff drift sheet. This line crosses the southeastern part of the quadrangle, with a lobe to Malone and a second to the hamlet of Skerry.

Malone Delta

In, and north of Malone, is the Malone Delta, one of the striking topographic features of the St. Lawrence Lowland. It is a wave-washed, flat-topped, pebbly sand deposit with a steep, lobate, northward-facing outer slope (figure 22b). It is now dissected by the Salmon and Trout Rivers, exposing glacial till and gravel below silt and pebbly sand capping. Kame gravels associated with the gray-buff till are seen at several places within the delta and northward from Malone. Along the west side of Salmon River are extensive kame deposits, and projecting through the pebbly sand cover are several smaller patches of kame gravel.

The pebbly sand capping lies on varved clay and silt, ranging in thickness from a few to a score of feet as seen: (1) at the Trout River bridge borrow pit, $1\frac{1}{2}$ miles northeast of Malone Junction; (2) along the New York Central Railroad cut, 1 mile north of Malone Junction; and (3) along the excavation for U. S. Highway 10, a mile north of the center of Malone. These occurrences show that the delta was built into a fresh-water lake.

The surface of the delta is pitted by six or more undrained depressions. Four of these are shown by two depression contour lines on the topographic map, indicating that they are 20 to 60 feet deep. They are depressions made when buried ice blocks melted out and let the surface collapse into the space. The valley of Salmon River through the delta area is composed of three large depressions whose shape and topography show ice-contact phenomena rather than fluvial trimming. The river has cut into the bottom of these depressions, and in the northern mile has excavated a little box canyon 30 to 50 feet deep into the Potsdam sandstone. It would appear then that the Salmon River Valley has been made largely by linking up ice-block depressions. The same line of reasoning applies to the elongate trough 2 miles northeast of Malone, followed by the New York Central Railroad. This depression is drained by an insignificant trickle of water, which could not have produced this major depression. It is evidently a feature of stagnant ice deposition. These topographic features demonstrate that deltaic silts and sands buried morainal topography and ice blocks of Fort Covington age. This lake episode followed shortly after the glacial episode. Since the surface stands at 700 to 730 feet altitude, it correlates with the Fort Ann stage of Lake Vermont in the Champlain Valley (Chapman, 1937).

Constable Delta

A second major pebbly, sand-covered, flat-topped area stands at the lower elevation of 500-520 feet near Constable and thence westward for about 3 miles (figure 22b). It is associated with the Salmon and Trout Rivers, and has been dissected by them and their tributaries, revealing buff till and occasional kame gravel covered by silt and capped with pebbly sand. Several northward-facing deltaic slopes are seen south of

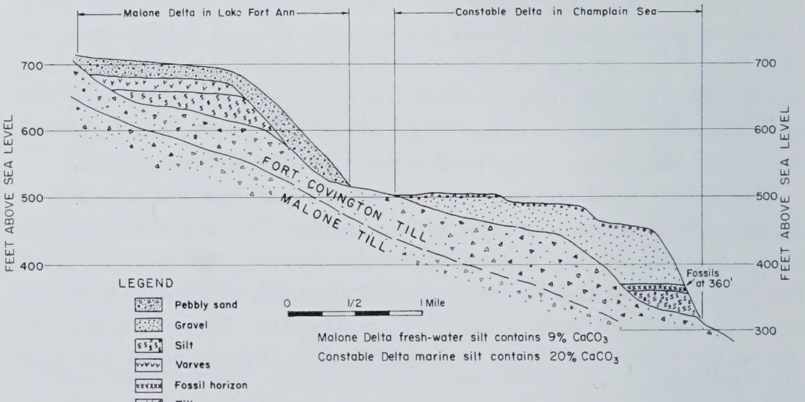
Malone Delta in Lake Fort Ann
Constable Delta in Champlain Sea
700
600
500
400
300
FEET ABOVE SEA LEVEL
FORT COVINGTON TILL
MALONE TILL
Fossils at 360'
LEGEND
Pebbly sand
Gravel
Silt
Varves
Fossil horizon
Till
0
1/2
1 Mile
Malone Delta fresh-water silt contains 9% CaCO3
Constable Delta marine silt contains 20% CaCO3

FIGURE 22*b*. Diagram of silt occurrences along Trout River, Malone quadrangle

Constable and north of Fay. One fairly large hill of till a mile southwest of Constable rises to an altitude of 480 feet. It is mantled with winnowed till, which has been heaped into low beach ridges parallel to the contour of the hill.

An excavation into the edge of the deltaic mass 1½ miles north of Gay, 4½ miles northwest of Malone, reveals 50 feet of dense silt over kame gravel and capped by 10 feet of pebbly sand. In the upper part of the silt, at an altitude of 360 feet and below the pebbly sand, are found *Hiatella* (= *Saxicava*) and *Macoma* shells, showing that this delta was built into the Champlain Sea. The silt here was compared with the silt of the Malone Delta, with mechanical and chemical analysis by the National Research Council in Ottawa, with the following results:

	Marine Silt 4½ miles NW Malone	Trout River Bridge 2 miles NE Malone
Sand	trace	22%
Silt	75%	61%
Clay	25%	17%
$CaCO_3$	20.2%	9%

The difference in the lime content appears to be significant, and might prove to be useful elsewhere in the region. One is tempted to explain the difference by saying that the silt at Malone was washed into the lake by rivers coming from Precambrian terrain and older drift, thus bringing less $CaCO_3$, whereas the waters of the Champlain Sea were acquiring lime from the freshly deposited calcareous till, as well as calcareous silt-bearing melt-waters.

Gravel bars and beaches are found in the vicinity of Constable, particularly to the northeast and east. These beaches lie along the contour of the land in descending order from about 500 feet in elevation. They are evidently beaches of the Champlain Sea, formed as the land rose.

The low-lying northern part of the quadrangle is composed of northeast-southwest trending masses of till, displaying frontal moraine topography which has been somewhat subdued by the Champlain Sea. This washing has left winnowed till in patches and beaches here and there on the moraine, and has deposited clay and silty sand in the lowlands. Fossil shells are found in many places in the winnowed till, as well as in the clay. Near the northern border of the quadrangle, 2½ miles east of Fort Covington, a gravel pit exposes the following section:

3. Horizontally bedded fossiliferous sand and gravel, 6-8 feet
2. Well-varved silt and clay, 6 feet
1. Outwash gravel, medium grained, 12 feet

This section is one of many such occurrences in the St. Lawrence Lowland which show that a fresh-water lake followed glaciation before the marine invasion.

In parts of the pit, fossiliferous clays and gravels are seen to lie directly on till. This may mean that (1) the varves were not deposited here; (2) that wave action during uplift in post-Champlain time eroded away the varves and deposited fossiliferous sediments on the till; or (3) that the lake was drained to sea level, which at that time was lower than the bottom of the lake, so that the varves were exposed to fluvial erosion before the sea rose and flooded into the St. Lawrence Lowland. This last suggestion is preferred because it also accounts for a phenomenon found in excavation and bore holes of the seaway, where the top of the varved clay is fractured and cracked, showing that it was exposed and dried out before being covered by marine clay.

The morainal belt crosses the quadrangle from about Trout River at the international boundary, through Fort Covington Center, 2 miles south of Fort Covington. The core of the morainal belt with hills rising 60 to 80 feet above the flats passes through Fort Covington so that, as previously stated, this moraine has been designated the Fort Covington Moraine, and its till the Fort Covington till.

The Salmon River Valley, 6 miles north of Malone, displays a flight of stream terraces. They vary in number, from place to place along the valley, to as many as five. The tops of the terraces display abandoned channel-way and meander scars, and are normally strewn with cobbly lag gravel, suggesting that these are all stream-cut terraces successively graded to the falling sea level as the land finally rose. They, therefore, may be correlated in time to the Champlain Sea episode.

Moira Quadrangle

The Moira quadrangle is mostly below 400 feet elevation, but rises as high as 1,000 feet in the extreme southeastern corner. The southern one-third is a sloping till plain, strewn with patches of pebbly sand beach and with about 25 hilltop areas of winnowed till. The central one-third is mostly a clay and sand-covered lowland, containing several extensive swampy areas of peat and muck, and the northern one-third is made of the northeast-southwest ridges of the Fort Covington Moraine, rising 60 to 80 feet above the clay-filled lowlands and capped by many elongate ridges of fossiliferous winnowed till. The winnowed till is piled into beach ridges in many places. A mile northeast of Bombay the beach ridges littering the north slopes were built as the land rose out of the sea. On the south flank of the hill, 2 miles east of South Bombay, a big gravel pit displays deltaic foreset beds (built of this beach material) to a thickness of 25 feet. At a depth of 20 feet below the surface, *Macoma* shells are seen in growth position, with the valves shut and intact.

One mile west of Bombay, the fabric shows orientation N50°W (Appendix M). This locality, at the crest of the Fort Covington Moraine, was selected as the type locality for the Fort Covington till. Till fabric 2 miles southwest of Moira (Appendix I-I) shows emplacement from the northwest. In like manner, striae in the valley of Little Salmon River, 2 miles south of Bombay, bear N 40°W. At Brasher Iron Works, west-trending striae are crossed by south-trending later striae. Along Deer River $1\frac{1}{2}$ miles south of Brasher Iron Works, striae bear N 80°E and N 70°E. These evidences, as in the Malone area, show two glaciations; the earlier from the east and northeast, and the latter from the northwest. The latter, Fort Covington episode, covered the whole quadrangle with the exception of about a square mile in the southeast corner, which lies above the strong terminal moraine through East Dickinson.

The pebbly sand deposits are scattered through the southern one-third of the quadrangle. The highest area of these lies in the extreme southeast corner of the map. Here at 1,000 feet elevation a mass of gravel is banked against the Precambrian hillside. Excavation of a large gravel pit displays foreset bedding of a delta which dips northward. The amplitude of these foresets is 125 feet parallel with slope of the hill, showing that the slope here is the frontal slope of the delta. The gravel is uniform, medium-fine gravel with practically no oversize. The stones are predominately Precambrian with only rare sandstone and no limestone, showing derivation from the south. This delta is the only such feature recognizable at 1,000 foot elevation on this quadrangle.

Near the south edge of the map, and a mile south of the village of Alburg, occurs approximately 2 square miles of pebbly sand with flattish top and north-facing delta lips. The upper edge of this deposit is at 700 feet elevation, the level of the Fort Ann stage of Lake Vermont.

No significant shore line deposits occur at the 500 foot marine level but just below that, around 450-460 feet, a row of beach deposits extend across the map from Brushton through Moira and Lawrenceville to the western edge of the map. This shore line is particularly marked north and northeast of Lawrenceville. Marine shells are common in winnowed till deposits to the north of this line. A mile northwest of Moira, fragments of shell are found in the winnowed till at elevation 399 feet, the highest occurrence yet found in this part of the St. Lawrence Lowland.

Nicholville Quadrangle

The Fort Covington ice crossed the Moira quadrangle and projected a few miles southward in the Nicholville quadrangle. The terminal moraine topography north of Lake Ozonia is composed of Malone drift. Shallow leaching shows Fort Covington till 1 mile northwest of Dickinson Center.

and in the kame gravels at Days Mills along the St. Regis River. Striae at the eastern edge of the lobe bear N 40°W to N 70°W. The western edge of the lobe lies just west of Hopkinton, with the red-brown till of northeast fabric lying beyond this edge. The boundary follows northwestward, on to the Massena quadrangle, to Stockholm.

The three shore lines cross the quadrangle, and their deposits lie on the buff till of the Fort Covington drift. There is a belt of pebbly sand and gravel shore deposits whose upper edge stands at 980 to 1,000 feet in altitude. This shows that 1,000 foot lake waters followed the Fort Covington episode, at least in this region. One of the best exposures, as seen in 1954, lay along the newly improved highway half a mile northwest of Dickinson Center. Here, 10 feet of calcareous buff till with fabric orientation from the northwest (Appendix I-Q) was exposed below 60 feet of bedded pebbly sand deltaic deposit, whose flattish top stands at 980-1,000 feet elevation. The St. Regis River had built a sandy deltaic deposit 3 miles to the west at this same level, and has since trenched it deeply. Gravel, partly deltaic and partly kamic, is exposed at Days Mills. Sandy shingle deposits on a beach ridge are seen 1½ miles southeast of Hopkinton, and the flattish shore line terrace passes off the map at about elevation 960 feet, 3 miles southwest of Hopkinton.

The Lake Fort Ann shore line is seen in sandy deltaic deposits along Deer River at about 700 foot elevation, and along St. Regis River at Water Street School.

Another deltaic deposit of the St. Regis River on this and the Potsdam quadrangles slopes gently from 600 feet at the south to 560 feet at the north, where it drops steeply to 500 feet along what might be a delta front, and thus represents a shore deposit of the Fort Ann Lake but, might equally well be a sea cliff of the marine shore line. Similar relations are shown along the west branch of the St. Regis River, and the Raquette River at Hannawa Falls.

Massena Quadrangle

The topography of this quadrangle comprises gentle, smoothly rounded, northeast-southwest hills rising 60 to 80 feet above wide flat lowlands. The hills, for the most part, are made of till, whereas the lowlands are underlain by clay and silty clay with, in parts, a coating of a few feet of sand. Well records show the drift to be 50 to 100± feet thick, lying on a roughly horizontal bedrock surface. The topography is a result of deposition of glacial drift followed by the washing and subduing effects of waves, tides, and currents of the Champlain Sea (figures 23a and 23b). It is estimated, as stated before, that the hills have thereby been lowered 30 to 50 feet, while the lowlands were aggraded a proportionate amount by the finer material washed from the hills (figure 24). Deposits of fossil shells of *Hiatella* (= *Saxicava*) and *Macoma* are widely distributed through the region. The shore line phenomena of the deep phase of the Champlain Sea lie on higher ground to the south of the Massena region, but scattered storm beaches, tidal beach flats, and sand plains were formed here and there, as the region finally rose out of the sea at the end of the Pleistocene. Rivers such as the Grass, the Raquette, and the St. Regis flow to the north and then northeast following the depressions among the glacial drift hills. They have cut only shallow channels through the silt and clay of the lowlands. The same phenomena hold true for the St. Lawrence River itself, which is made up of channels that spill among the glacial hills and have cut into and exposed the Champlain Sea, as seen along parts of both the north and south shores of Barnhart Island.

Foundation excavations in 1953 for the new hospital in the northwestern part of Massena exposed 5 or 6 feet of sandy, loose rubble containing *Hiatella* shells lying on dense, silty, oxidized, but calcareous till. The lithology of the rubble layer is the same as the till below, showing that it was derived therefrom by the winnowing action of the waves of the Champlain Sea, in which the *Hiatella* shells grew. The silt and clay

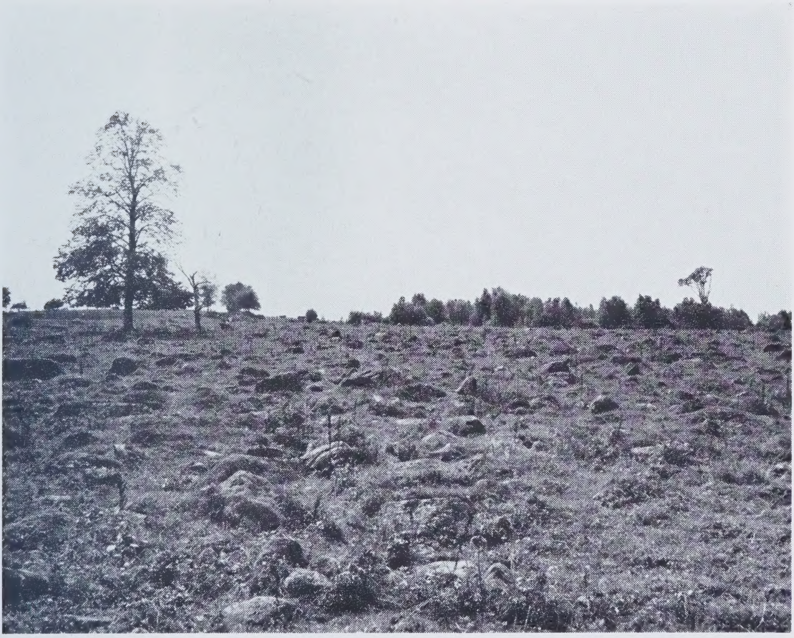

FIGURE 23*a*. Boulder-strewn shore line slope at altitude of 380 feet, 1 mile west of Stockholm Center, Massena quadrangle

Photograph by J. Heller

from the till had been washed away into the surrounding depressions, where they had accumulated as flat plains of deposition. In many lowlands clay and silty clay are exposed at the surface, but in other places a thin layer of sand may form the surface material. Not uncommonly, this sand has been blown into patches of dunes. The blanket of winnowed till is a residual marine sedimentary deposit accumulated *in situ.*

On top of the hill where the hospital stands, the rubbly and bouldery winnowed till forms long low ridges about 10 feet high and 100 yards long, which are strewn with boulders. These ridges are believed to be storm beach ridges piled by the waves of the ancient sea.

The best display of beach phenomena in the area is seen on the hill 3 miles southeast of Massena Springs, locally known as Maple Ridge. It is a conspicuous hill, standing well above its surroundings on all sides. The crest of the hill has been excavated for gravel, leaving a large shallow pit exposing very coarse, poorly sorted, winnowed till studded with *Saxacava* shells and shell fragments. This blanket of coarse material must have formed locally, as waves of the Champlain Sea winnowed the fine material from the till to leave this as a residual sedimentary deposit.

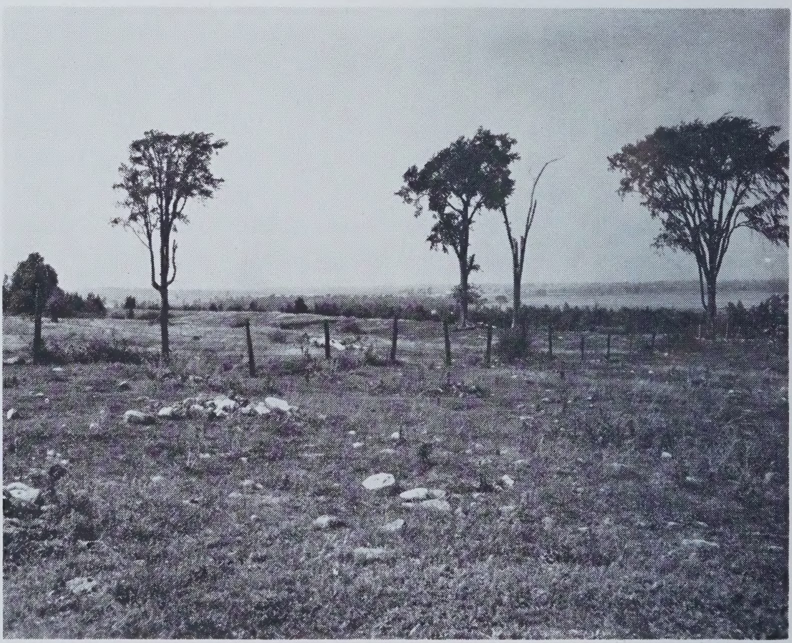

FIGURE 23*b*. Beach ridge on the north slope of Maple Hill, 3½ miles southeast of Massena Springs, Massena quadrangle

Photograph by J. Heller

Piles of large boulders and blocks are abandoned on the bottom of the pit. Some are very slightly rounded, and others are striated.

The north flank of the hill is made of a succession of 6 to 8 roughly parallel low ridges, like storm beaches, composed of poorly sorted, rough, bouldery gravel. These low ridges are 6 to 15 feet high and 50 to 100 feet wide (figure 23b). Laterally they merge and part, are a little higher or lower, or even flatten out altogether. This is characteristic of storm beaches along present-day shore lines. A gravel pit on the southeast flank of Maple Ridge has been excavated in one of these storm beaches of winnowed till, which is here about 6 feet high. The pit is about 15 feet deep, and shows a blanket of winnowed till about 12 feet thick, the surface of which has been heaped into storm beaches. Dense silty till, strewn with *Saxacava* shells, is exposed on the floor of the gravel pit.

A gravel pit at the top of a low hill 1 mile north of Massena, near the old canal, is illuminating. The floor of the pit is strewn with large boulders and blocks; the face is badly slumped but is evidently made of winnowed till, and contains a few shell fragments. The top surface of the hill is a mosaic of large boulders. This boulder field extends northeast-

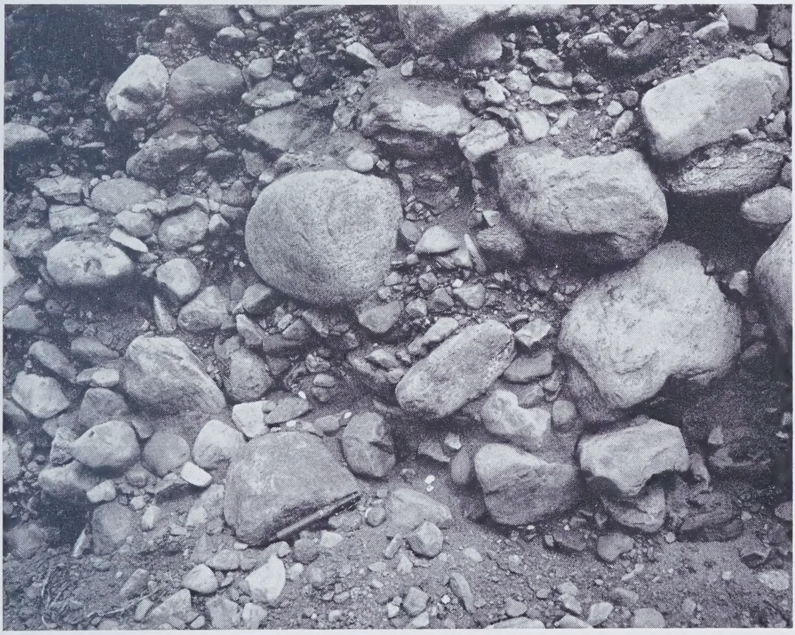

FIGURE 24. Fossiliferous winnowed till beach gravel. Raquette River Village, Massena quadrangle

Photograph by J. Heller

ward to the bank of the canal, which has here been cut through a mound of till to expose about 50 feet of dense blue-gray till oxidized to a depth of about 12 feet. At the brink of the canal bluff, 2 to 4 feet of the winnowed till whose top surface is strewn with boulders is seen to lie on the dense till. A few hundred feet to the north, along the same bluff, the dense till is seen to extend completely to the land surface, but still this surface is littered thickly with boulders. Hence, the presence of boulder concentration alone does not show the presence of winnowed till. Two mechanisms seem to have been at work. The winnowed till is a blanket of fossiliferous debris, made by churning up of the surface part of the till and the winnowing out of the silt and clay, leaving the residue with the marine shells in it. From the number of boulders in it, as contrasted with the number in the dense till, it is estimated that about 2/3 of the original till has been washed away. The other mechanism which produced a boulder-strewn surface, where the boulders lie directly on dense till, seems to have resulted in a washing of the surface without the churning-up process. It might be that one was the churning action of waves, and the other the washing action of currents. In field discussion it was useful to designate the one as "washed-out" till, and the other as "washed-off" till. The question arose whether or not it is possible to distinguish and map the two phenomena simply by surface topography. After much laborious digging of test pits and drilling with a 4-foot soil auger, a fairly consistent relationship was established. If the microtopography of a few feet of relief shows parallel ridges or gently branching and joining ridges rather parallel to the contours of the hill, they are beach ridges and a deposit of winnowed till may be mapped. On the other hand, if the low boulder-strewn ridges make rough circles or interlocking circles and till is encountered among and below the boulders, it seems normally to be subdued morainal topography and the area should be mapped as till (washed-off till). Maple Ridge, 3 miles southeast of Massena Springs, is an ideal place to study the former phenomenon of beach ridge topography; the hill ½ mile southeast of Massena Center shows the latter.

Kame Terrace

The hill 3 miles northeast of Norfolk is covered with winnowed till, heaped into a flight of boulder-strewn storm beaches. But at the northern base of the hill, the lowest ridge is revealed in a large gravel pit to be composed of well-rounded and well-sorted ice-contact gravel which contains no fossils. It is proposed that this low ridge is a kame terrace, which persisted through the Champlain Sea episode with only slight surface modification.

Outwash Gravel

About 3 miles south of Massena Springs lies an occurrence of outwash gravel. The top of the hill has been excavated for aggregate used in construction of the Massena airport, and displays 25 feet of fossiliferous winnowed till on 10± feet of clean, horizontally bedded, well-sorted, medium-sized, outwash gravel which in turn lies on dense till in the bottom of the pit. The large pits on the southern flank of the hill expose about 15 feet of fossiliferous, bouldery, winnowed till lying on horizontally bedded, clean, medium-sized, nonfossiliferous gravel. The horizontal stratification shows the gravel to be part of a glacial outwash plain. At the southwest end of the pit, the outwash gravel is capped by several feet of fossil-bearing (*Macoma*) sand, which mantles extensive lowland flats surrounding the hill.

Farther south 6 miles and 6 miles southeast of Raymondville, the gravel pit along Regan Road is about 30 feet deep in gravel, containing cobbles and boulders. At the north end of the pit, 9 feet of medium gravel containing shell-fragments lies on 8± feet of clean, sharp, sand containing whole *Saxacava* shells to a depth of 15′-18′ below the land surface. Along the east side of the pit, the upper gravel displays deltaic foreset bedding dipping southwestward. This deposit came to rest in the Champlain Sea, as shown by the fossils, but because the pebbles, cobbles, and boulders are so well rounded it is thought to have been derived from a deposit of Kame gravel, rather than of till. The kame may well lie concealed under the northern part of the hill.

Another good case of redeposited kame gravel is to be seen in the pit a mile west of Massena. This pit is dug into the northwestern slope of the long till hill on which the city of Massena has been built. The summit of this hill, 1 mile west of town, is capped by a beach ridge of fossiliferous winnowed till about 10 to 15 feet thick. The upper and eastern parts of the gravel pit are in this material, but the western and lower parts of the pit have encountered such well-rounded material that a source in kame gravel is postulated instead of till. It contains *Hiatella* and *Macoma* shells, showing that it was redeposited in the Champlain Sea.

Another illuminating exposure is found in the gravel pit 2 miles southwest of Norfolk. The pit is at the southwest end of a long beach ridge of winnowed till which mantles the hilltop. The upper 10 feet of the pit exposure shows rubbly sand and gravel without fossils. Below, judging from its size and shape, occurs kame gravel. But in the bottom of the pit, 20 feet below the original surface, fossil shells of *Macoma* and *Mytilus* were collected from clean, sharp, sand. Till containing striated boulders is seen in the bottom of the pit. These relations show how the deposit was made by the transport of sediments by the Champlain Sea from the higher ground, to the north, where the hill is now covered with northeast-southwest storm beaches made of winnowed till. It follows that the smoothly rounded shape of the majority of the hills of the region may be partly due to the washing of the Champlain Sea.

Fort Covington Drumlins

A striking bit of topography occurs a mile south of Massena Center. It consists of a group of very regular, parallel, small symmetrical till ridges 50 to 60 feet high, about 200 feet wide by ½ mile long. These ridges have a north-south orientation athwart the normal northeast-southwest trend of the main hill. They are littered with a mosaic of boulders. In the troughs between the ridges the auger brings up clay below a foot of sand among scattered boulders, showing that the ridges were formed prior to, or contemporaneous with, the Champlain Sea. A similar group is seen crossing the hill 3 miles southwest of Massena. They are small drumlins of Fort Covington till on top of Malone till.

Margin of Fort Covington Drift

The southern margin of the Fort Covington drift lies in the southeast corner of the quadrangle, south of Stockholm. Exposures are not present on the Massena quadrangle to demonstrate this fact, but on the Potsdam quadrangle, to the south, two good exposures of red-brown Malone drift at Hayes School, a mile east of West Stockholm, and at Buckton, demonstrate the presence of the border.

Oxidized Till Below Unoxidized Clay

Occurrence of oxidized till below gray, unoxidized, clay was well displayed along the Long Sault Island Cutoff diversion trench (cut "C"). When the "Friends of the Pleistocene" group visited the cut in May 1955, it was agreed that, since a layer of water-bearing sand and gravel lay at the contact, the staining could have been accomplished by ground water, particularly since there was no sign of leaching or soil profile development below the contact. At the southwest end of this diversion trench, a zone of springs issues at the contact and trickles down across the surface of the till, which is seen to be stained here. Also, in the bottom of the excavation for the Long Sault Powerhouse at the east end of Barnhart Island, 6-inch holes drilled for the purpose of grouting the bedrock penetrated a 2-foot layer of gypsum at a depth of 40-50 feet, and water flowing from these drill holes in July 1955, had a strong sulphur smell and taste. Where it had run for only a few weeks, it stained yellow-brown the surface of the pipe, the gravel, and the till. At Massena Springs, 3 miles to the southwest, on the north bank of Raquette River, there has long been famous the "medicinal" waters of the Massena Springs, which also have a sulphurous smell and taste, and doubtless arise from the gypsum bed below. It is a tenable hypothesis that the buff staining of the till below the clay is the result of circulation of the iron-bearing sulphate waters spreading below the less pervious clays.

Permanent Bridge Pier

At the excavation on Barnhart Island, for the north pier of the permanent bridge, fresh-water varved clays 10 feet thick lie on buff-stained calcareous till and are, in turn, overlain by 10 feet of fossiliferous, silty, marine clay. Nowhere is there evidence of leaching. The vertical section in the cut for the access road to this excavation shows:

5. Fossiliferous marine sand and silt	10′ thick
4. Varved clay and silt fractured and faulted in its upper part	10′ thick
3. Iron-stained gravel, silt, and till	3′ thick
2. Buff sandy till	5′ thick
1. Blue-gray sandy till	5′ thick

The conclusion, then, is again deduced that a fresh-water environment followed glacial retreat, prior to invasion by Champlain marine waters. Emergence with desiccation of varved clay may have occurred before submergence by the sea. Oxidation of the till below the varves is again probably due to either staining by ground water, or oxidation during exposure to the atmosphere.

Excavation of the Eisenhower lock exposed, in 1955, 10 feet of fossiliferous winnowed till, which has been washed down the gently sloping eastern side of a till hill onto 10 feet of varved silt and clay, which in turn lay on blue-gray Fort Covington till. The contact between the varved clay and the till is undulatory, as though it were the irregular depositional surface of till on which the lake sediments accumulated prior to the invasion of the Champlain Sea.

Stratigraphy in the Excavations for the Seaway and Power Projects

By the summer of 1956, nine major excavations were open to study. In the following descriptions no attempt is made to measure or describe precise thickness and distances. The engineering specifications and descriptions are accurate to a fraction of a foot, and the drawings are all to scale, but for geological interpretation generalized diagrams are sufficient.

Grass River lock. The Grass River lock lies at the eastern end of the International Rapids section of the seaway. It is located a half mile west

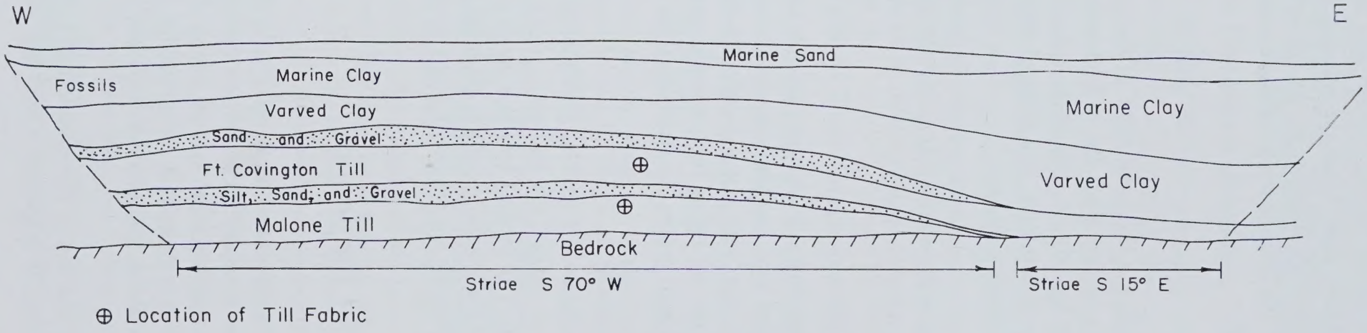
W
E
Marine Sand
Fossils
Marine Clay
Marine Clay
Varved Clay
Sand and Gravel
Ft. Covington Till
Varved Clay
Silt, Sand, and Gravel
Malone Till
Bedrock
Striae S 70° W
Striae S 15° E
⊕ Location of Till Fabric

FIGURE 25. Diagram of Grass River lock excavation, north face

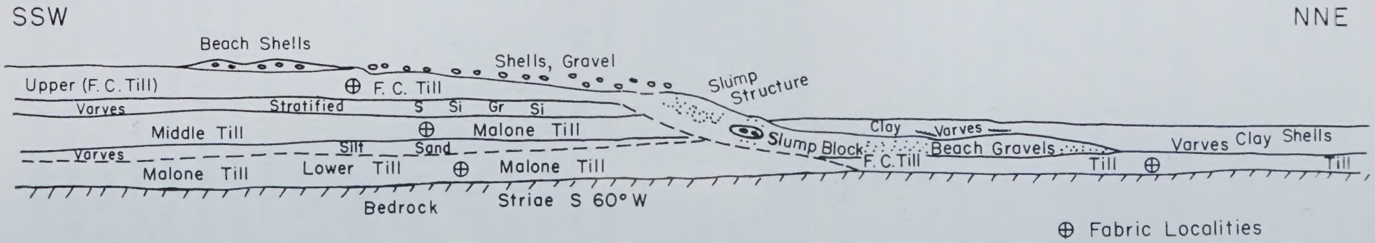
SSW
NNE
Beach Shells
Shells, Gravel
Upper (F. C. Till)
⊕ F. C. Till
Slump Structure
Varves
Stratified
S Si Gr Si
Middle Till
⊕ Malone Till
Clay
Varves
Varves Clay Shells
Slump Block
Beach Gravels
Varves
Silt
Sand
F. C. Till
Malone Till
Lower Till
⊕ Malone Till
Till ⊕
Till
Bedrock
Striae S 60° W
⊕ Fabric Localities

FIGURE 26. Diagram of Eisenhower lock excavation, east end

of the mouth of the Grass River, where the latter joins the St. Lawrence. The excavation, about 100 feet wide at the bottom by 1,200 feet long, went down through clay and drift to lay bare the bedrock upon which the lock was built. Before the concrete was poured, the bedrock was thoroughly washed with high-pressure hoses so that glacial striae in almost unprecedented magnitude and freshness were laid bare to view. In the central and western part of the excavation, these striae trend N 70°E with details of stoss and lee to show movement from northeast toward southwest. These striae are quite uniform over a surface about 60 to 600 feet in area. Toward the western end of the exposed bedrock, a small gully cut in the bedrock about 10 feet deep lies almost east-west and exhibits striae on its walls and bottom. It was evidently present and followed by the basal currents of the ice. At the eastern end of the excavation, on the other hand, in an area at least 75 by 100 feet, the striae bear N 15°W.

Striae on the limestone of the Barrett quarry a mile south of East Norfolk which bear N 65°E, are crossed by a younger set of striae, with bearing N 10°W. These latter striae descend into and across the earlier set. This situation is seen on the south rim of the pit, where excavation has stripped about 15 feet of buff till from the limestone. Quarrying operations are pushing the face southward so that the striae may not be preserved very long. They do, however, confirm till-fabric evidence that there have been two directions of ice motion in the area, one from the northeast and later, one from the northwest. These two sets of striae are overlain respectively by the Malone and the Fort Covington tills, as shown by respective till-fabric analyses (figure 25, Appendix I-MM and XX). This site demonstrates Fort Covington till lying on the bedrock, and suggests either an episode of fluvial erosion between deposition of the two tills or erosion of the Malone till by Fort Covington ice. The tills are overlain by Lake Vermont varved clays, and by Champlain Sea clays and sands.

Eisenhower lock. The excavation for the Eisenhower lock cuts through one of the typical northeast-southwest hills of the region (figure 26). At each end, the excavation passes down through the marine clays of the lowlands into Fort Covington till, but in the middle, it goes down through till to bedrock. In this cut, three distinct layers of till were displayed, separated by stratified drift within which are zones of varved silts and clays 8 to 10 feet thick. The stratified layers were measured with the hand level, and proved to be horizontal to within a foot or so, from one end of the exposure to the other. The bottom till lies on bedrock striated N 60°E, and shows fabric orientation (Appendix I-NN) in the same direction. The middle till of the section shows a similar fabric orientation, and so belongs to the same episode (Appendix I-OO). On the other hand, the upper till shows orientation from the northwest (Appendix I-YY). These facts allow correlation to be made, the lower and middle tills being Malone and the upper being Fort Covington. At the crest of the hill, as mentioned earlier, fossil-bearing beach gravels of Champlain Sea origin occur. In the lowland at the east base of the hill, also, Champlain Sea deposits of fossiliferous clays occur. These clays in the lowland lie on Lake Vermont varved clays, which in turn rest on Fort Covington till, as shown by its fabric. So here, as in the Grass River lock, the Fort Covington till comprises the crest of the hill and drapes down to underlie the lowland as well. At the east brow of the hill an excavation beside an access road reveals a bluff 20 feet high of crumpled till, stratified silts, gravels, and sands. The involutions are 10-15 feet across, and are obviously the result of subaqueous slumping. About a hundred feet down the slope of the hill two or more masses of till are slumped into crudely stratified ma-

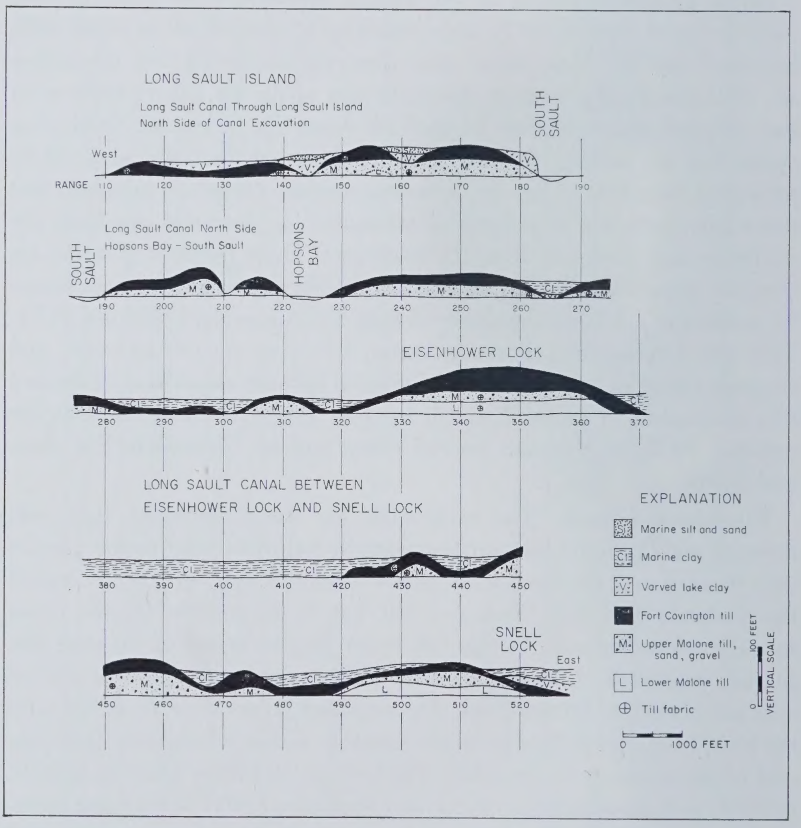
LONG SAULT ISLAND
Long Sault Canal Through Long Sault Island
North Side of Canal Excavation
SOUTH SAULT
West
RANGE 110 120 130 140 150 160 170 180 190
Long Sault Canal North Side
Hopsons Bay – South Sault
SOUTH SAULT
HOPSONS BAY
190 200 210 220 230 240 250 260 270
EISENHOWER LOCK
280 290 300 310 320 330 340 350 360 370
LONG SAULT CANAL BETWEEN
EISENHOWER LOCK AND SNELL LOCK
380 390 400 410 420 430 440 450
SNELL LOCK
East
450 460 470 480 490 500 510 520
V
M
L
Cl
EXPLANATION
S Marine silt and sand
Cl Marine clay
V Varved lake clay
Fort Covington till
M Upper Malone till, sand, gravel
L Lower Malone till
⊕ Till fabric
0 1000 FEET
0 100 FEET VERTICAL SCALE

FIGURE 27. Relation of Fort Covington and Malone drifts shown in the canal excavation

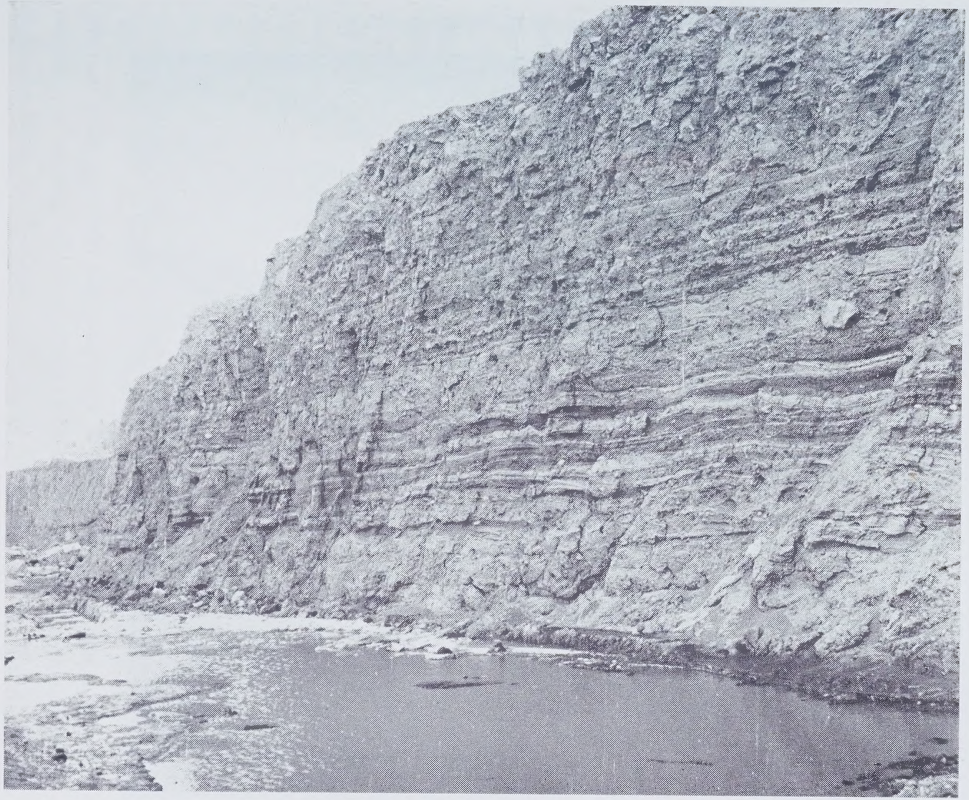

FIGURE 28*a*. Structure of Upper Malone drift in Iroquois Dam excavation

Photograph by John Harris, N. Y. S. Power Authority

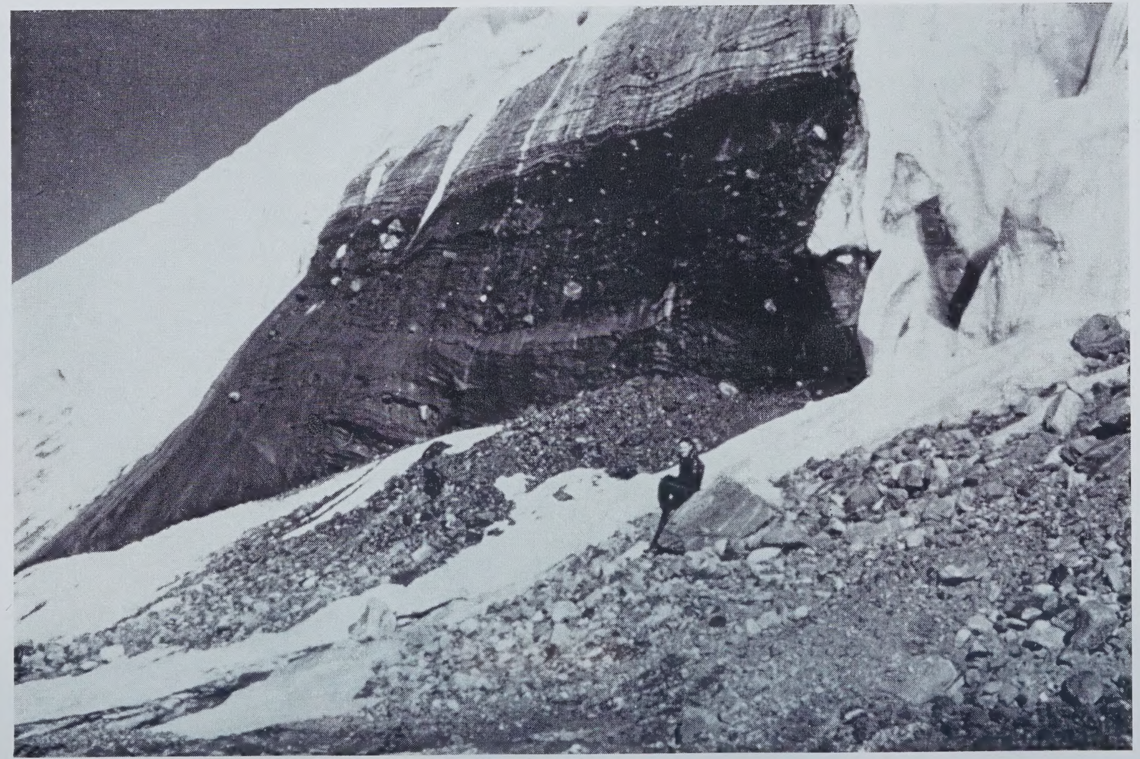

FIGURE 28*b*. Structure of debris-laden Greenland ice sheet

terial, like a near-shore beach deposit. At the top of this latter material occur 10 feet of varves below fossiliferous Champlain clay. It would appear, therefore, that the slumping occurred in the waters of Lake Vermont. Later, the waves of the Champlain Sea washed the hilltop to deposit the fossiliferous beach gravels. The demonstration here of subaqueous slumping in the lake waters opens up a major vista for the interpretation of till-like deposits on hill slopes and in depressions. This is doubtless the material encountered in test borings which the engineers described as "reworked till," because it lacked the engineering characteristics of fresh till. It might be expected that Fort Covington morainal topography would be rough and unstable, and disposed to subaqueous slumping. This would be true particularly on the slopes of the hills where the Fort Covington till drapes over the middle and lower Malone till section. None of the exposures showed the younger till actually transecting the stratified bed between the two Malone tills (figure 27).

Upper Malone Drift, Its Character and Origin

The Upper Malone drift, or middle till complex, as it has been described in the field, is widely exposed in the seaway and power project excavations. It is composed of a suite of sediments which include (1) layers of sand and gravel, (2) layers of silt, (3) layers of varved silt and clay, and (4) layers of till as well as flattish masses of till. In many of the exposures it displays major horizontal stratification, which can be traced continuously for 100 yards or more along an exposed face of the excavation (figure 28a). Fabric analyses made in the layers of till show them to have been emplaced from the northeast. Much of this till exhibits a crude horizontality called by Flint (1957, p. 113) "roughly horizontal fissility." It is most obvious on water-washed surfaces where it stands out in bas-relief. Similar structure in tills of Finland are described by Virkkala (1952), and attributed to deposition directly by ice that was layered into drift-filled laminae, separated by beds of pure ice. This kind of structure in glacial ice has been described by many observers. When the lower drift-rich ice layers lost their plasticity by the concentration of drift in the basal glacier ice, and consequently their ability to move, they caused deposition of till. Overriding, drift-bearing, moving ice doubtless shoved forward underlying material, with more or less distortion. The major stratifications of sand, gravel, and silt between layers show the deposit to be subaqueous in origin. The presence of varved clays shows it to have been deposited in fresh water. Because of these phenomena, the Upper Malone drift (middle till complex) is thought to be the product of oscillatory waning of Malone ice while standing in waters of an ice-dammed lake.

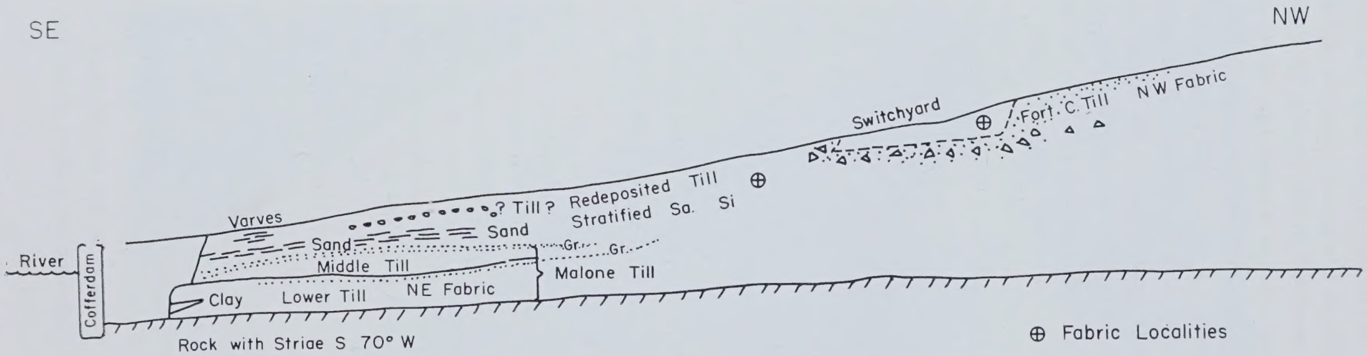
SE
NW
Switchyard
Fort. C. Till
NW Fabric
Redeposited Till
? Till ?
Stratified Sa. Si
Varves
Sand
Sand
Gr.
Gr.
Middle Till
Malone Till
Clay
Lower Till
NE Fabric
River
Cofferdam
Rock with Striae S 70° W
⊕ Fabric Localities

Figure 29. Diagram of Barnhart Island powerhouse excavation

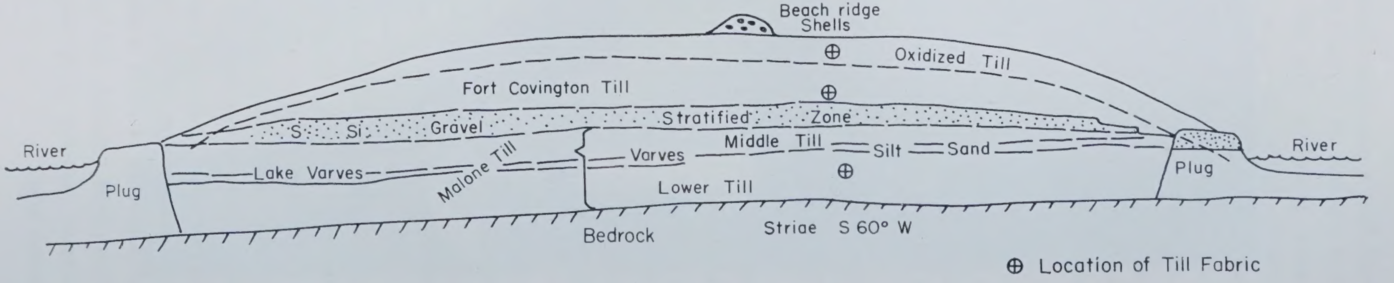
Beach ridge
Shells
Oxidized Till
Fort Covington Till
S Si Gravel
Stratified Zone
Middle Till
Silt
Sand
Varves
Lake Varves
Malone Till
Lower Till
River
River
Plug
Plug
Bedrock
Striae S 60° W
⊕ Location of Till Fabric

Figure 30. Diagram of cut "F," north side

Another origin is proposed by Harrison (1957 and personal discussion). He demonstrated that till fabric was produced within the flowing glacier, and very slowly let down when the ice stagnated and gradually melted out of the debris. If this be the mechanism of till-fabric genesis, there is no reason why stratification within an active glacier could not be let down on to the glacier floor the same way. Figure 28b shows a vertical edge of the Greenland Glacier east of Thule, Greenland. If this ice should stagnate and slowly melt away, it might produce the structure seen in the middle till complex, for the till masses lie between obviously lacustrine and outwash layers.

Barnhart Island Powerhouse. This excavation cut down through drift to bedrock, exposing striae trending S 70°W. On bedrock lies dense Malone till, containing irregular and crumpled masses of varved clay, some layers and zones of which are smooth and fatty (figure 29). The till fabric shows origin from the northeast. A thin gravel layer intervenes between the lower and middle tills, and another between the middle and upper tills. Above the upper till lies 5 feet of sand and gravel, below 15 feet of varved clays. In 1954, the upper till and varves were displayed for study. By 1955, the excavation had removed them and had displayed a 50-foot section of stratified sands and silts with masses of bouldery till-like material. Fabric analysis of this material showed random orientation (Appendix I-BBB). It is therefore inferred that this slump material was derived from Fort Covington till farther up the hill, as seen in the switching yard excavation (Appendix I-AAA).

Forebay Dike Borrow Pit. On the north side of Barnhart Island, 1 mile northwest of the powerhouse, a borrow pit was dug to supply material for the dike. This excavation showed 2 or 3 feet of loose buff till, containing large boulders, which lies on very dense, tough, till about 25 feet thick. A till-fabric analysis shows this lower till to be from the northeast and hence to be Malone till (Appendix I-PP). The upper thin layer is doubtless the Fort Covington till. At the time of a visit in 1956, this upper till had been largely stripped away and discarded as unsuitable for dike construction. In the northwest corner of the excavation, about 40 feet of loose material (somewhat like till but showing crude and undisturbed bedding) is interpreted as slumped material.

Long Sault Dam, South Abutment. During the summer of 1955, this excavation was open to study. The cut exposed about 100 feet of till down to bedrock, with striae N 60°E. Tension and shear-cracks show ice moving to the southwest. Lying on the bedrock is dense, compact, till about 20 feet thick, which has fabric orientation also from the northeast (Appendix I-QQ). This till is so dense that during test boring the engineers have been able to extract drill cores of the material. At the top of this lower till is a zone about 10 feet thick in which silt and clay are intimately mixed, with masses of varved silt and clay infolded, and carried up into overlying till. So intricate is the involvement that this zone was impossible to map. Some masses of the involved silt and clay still show varved layers. This phenomenon shows a proglacial lake deposit overrun by glacial readvance. Some specimens of the varved material are sheared, compressed, and virtually "schistose" in appearance. The top of the clayey zone contains layers of till, with fabric again showing movement from the northeast (Appendix I-MM). Till at the top of the excavation is oxidized to a depth of about 20 feet, but at a depth of 10 feet below the ground surface the oxidized till still has fabric showing emplacement from the northeast (Appendix I-SS). It is inferred that the entire exposure is Malone till, and that the Fort Covington till was so thin that it was removed during the wave-washing that produced the fossiliferous, winnowed, till beach ridge, which now caps this hill of the excavation. Northwest fabric shows the south slope of the hill to be covered with Fort Covington till.

Cut "F." Cut F was an excavation through Long Sault Island, 1½ miles west of the Long Sault Dam abutment. This cut was about ¼ mile long, about 600 to 800 feet wide, and 70 to 90 feet deep through till to bedrock (figure 30). The river was diverted through here while the Long Sault Dam was being completed in 1956. Bedrock was bare over extensive areas and striated N 60°E. Lying on the bedrock is dense till with fabric from the northeast (Appendix I-TT). About 20 feet up occurs a horizontal zone of sand, silt, and gravel containing 8-10 feet of varved silts and clays. Above this stratified zone, another layer of till about 20 feet thick is seen. Above this latter till occurs a major zone of stratified drift, in turn overlain by an upper till 30 to 40 feet thick. This upper till is oxidized to a depth of about 18 feet. Till fabric in both the oxidized and the unoxidized parts of this upper till shows it to have come from the northwest (Appendix I-CCC, DDD). This upper till, therefore, is correlated as Fort Covington, and the two lower till masses are Malone.

Power Canal Intake. An excavation for the intake works of the Massena power canal exposed a deep section of drift down to bedrock. Extensive patches of striae on bedrock trend S 60°W (figure 31). Lying on the bedrock is 30 feet of very dense basal till, above which is a 40-50 foot zone of stratified, subaqueous, till lake sediments and fluvioglacial drift in complexly disturbed bedding. About the middle of the exposure, a till-fabric study (Appendix I-CCC) shows it to have come from the northeast. The lower and middle drifts are, therefore, correlated with Malone till. Above a sand, gravel, and silt zone occurs 30 or 40 feet of upper till, with fabric showing its origin from the northwest (Appendix

I-PP). At the southeast base of the hill, marine fossiliferous clay lies on 6 feet of varves on till. The canal intake excavation cuts through one of the major northeast-southwest drift hills. The core of the hill is found to be of Malone drift, but the surface is Fort Covington drift, which drapes down into the lowlands on either side (Appendix I-EEE).

Long Sault Rapids

Construction of the Long Sault Dam as part of the St. Lawrence River power project involved blocking off by cofferdams and pumping dry the Long Sault Rapids (figure 32). This exposed the bed of these spec-

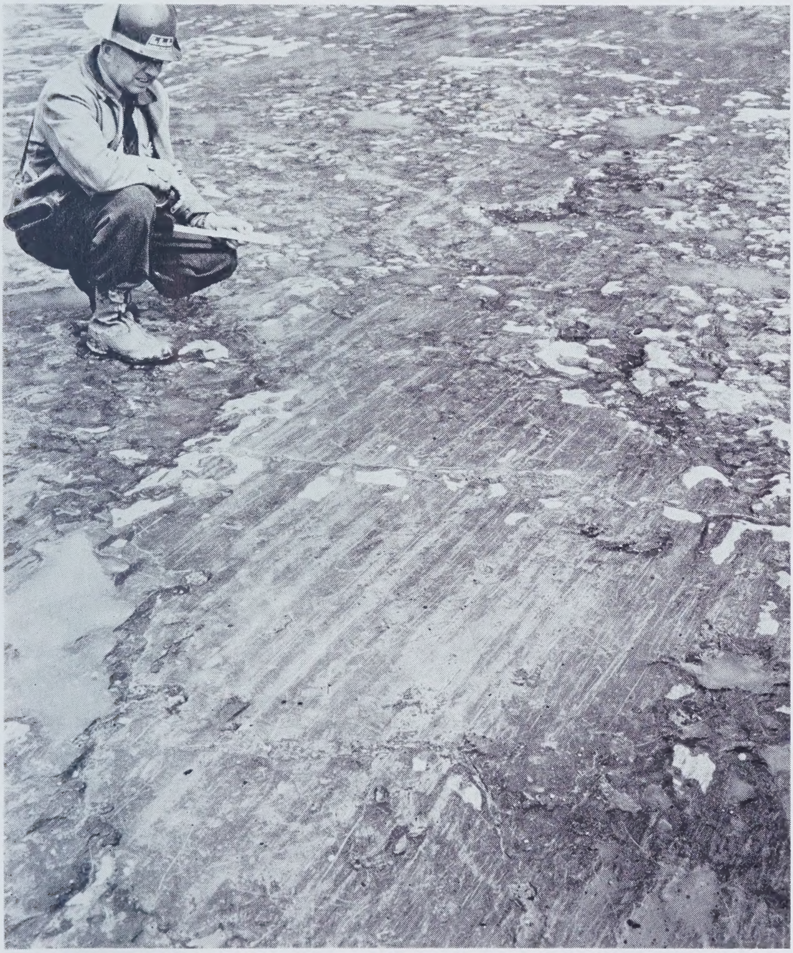

FIGURE 31. Striae oriented S 62°W, power canal intake
Photograph by W. Thompson, N. Y. S. Power Authority

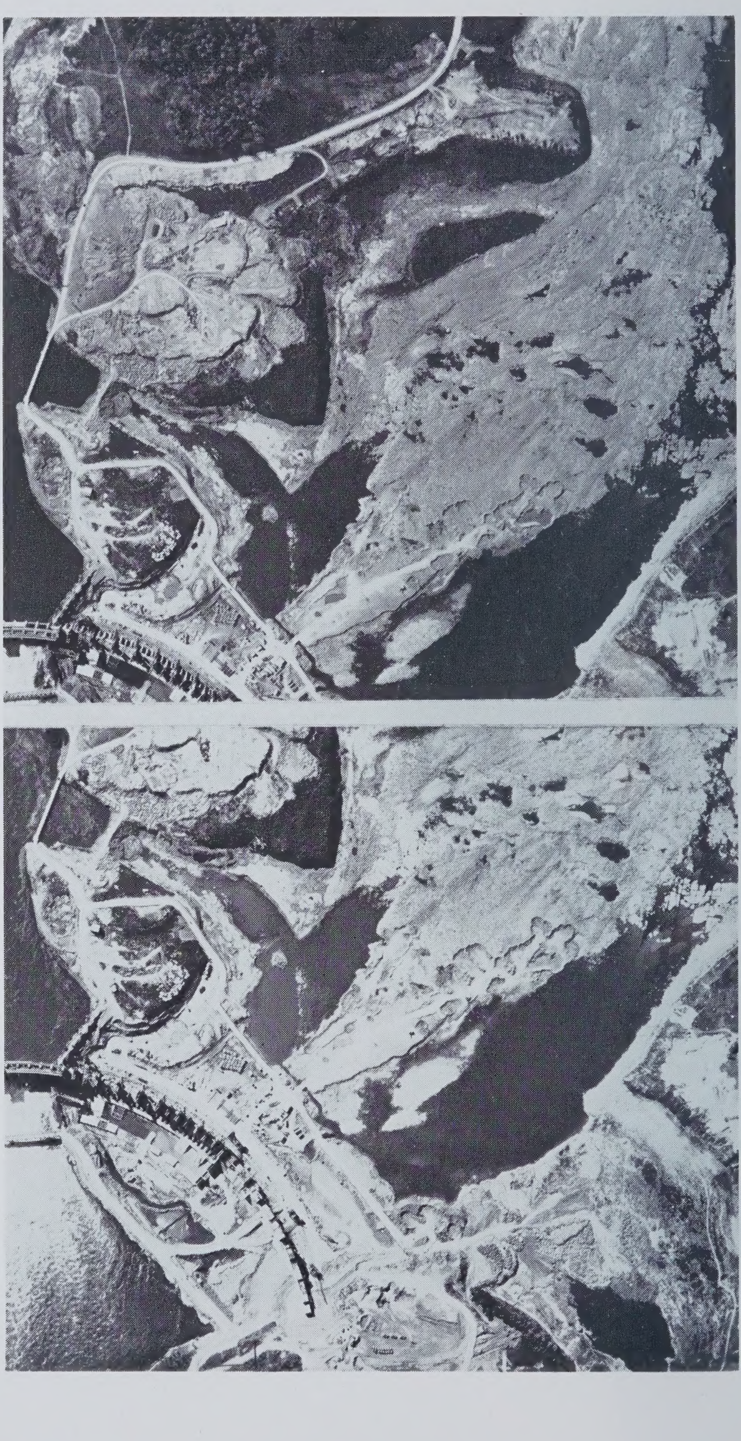

FIGURE 32. Air photo stereo pairs showing Long Sault Rapids blocked off by cofferdams during construction

tacular rapids, and revealed the cause for the great standing waves which so impressed the early French explorers and gave rise to the name Long Sault or "long leap" rapids. The discharge through the rapids averaged 220,000 cubic feet per second, descending 33 feet in 8,000 feet or 22

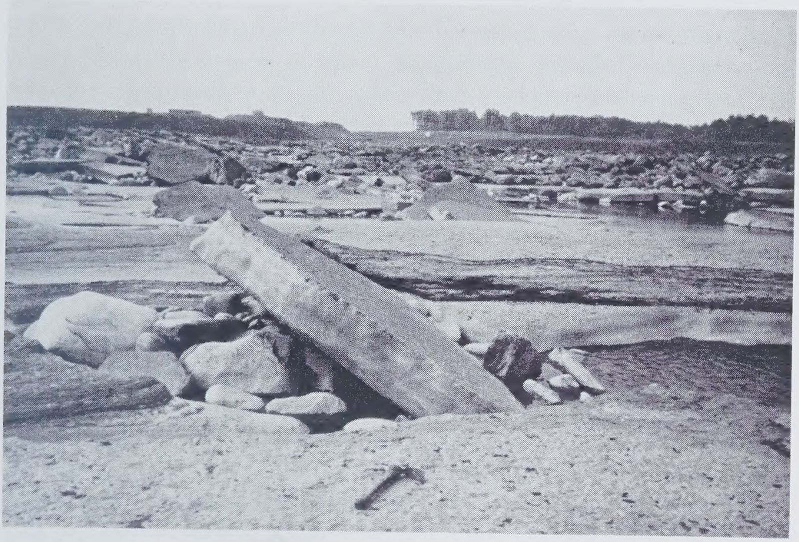

FIGURE 33*a*. Shingled slabs of limestone, Long Sault Rapids

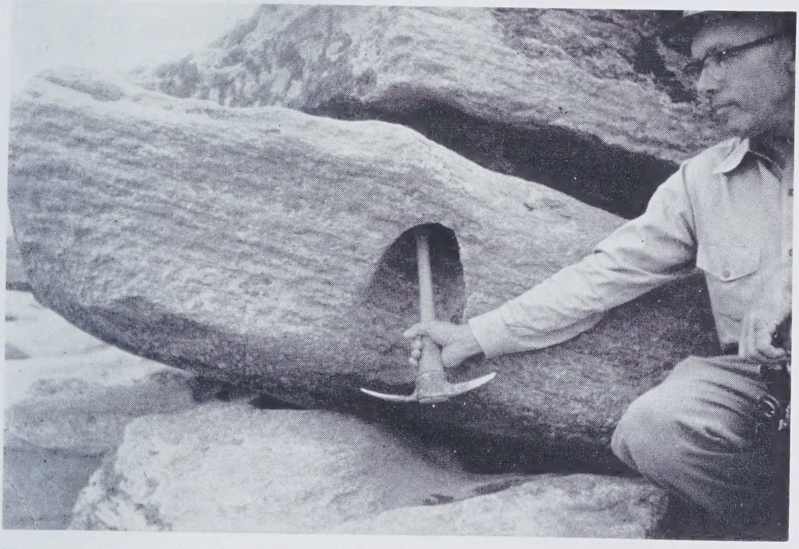

FIGURE 33*b*. Upside-down pothole in inverted slab, Long Sault Rapids

feet per mile. The current was measured at two places at 10.0 mph and one place at 11.5 mph. The floor consists of limestone, with thin partings of shale, dipping very gently downstream (south-eastward). The bed is covered on the inside of the bend with coarse gravel and boulder-bar material, but where the main current had been, the limestone is either bare or is strewn with large slabs of limestone evidently picked up by the torrent and moved downstream to their present places. Many of them measure 10 by 15 by 3 feet. The majority of these slabs now rest in a position dipping upstream at an angle of 30° or more (figure 33a). Some of them are caught in joint cracks in the bedrock, others rest on each other, and still others lie on rounded boulders and cobbles. Those wedged into cracks in bedrock may dip 50° or 60°, but the measurement of 56 of these slabs gave an average dip of 36°. They produce a shingled arrangement dipping upstream. Cross-bedding on the edges of the slabs, as well as potholes projecting upward on what is now the bottom, show that many of the slabs have been flipped over and now rest upside down (figure 33b). It is obviously these slabs which produced the great waves of the rapids. To confirm this conclusion, the air photo of the original rapids was compared with the air photo of the dry river bed. After the two photos were brought to the same scale, the "white water" on the rapids was circled on tracing paper, which was then superimposed on the photograph of the bed. The coincidence was entirely convincing. On the inside of the bend, in what had been shallower water, many large glacial boulders each produced a patch of "white water." The gravel bar part of the bed exhibits longitudinal bars and depressions, with relief of 8 to 10 feet. At its downstream end, however, are found seven large transverse depressions about 50 by 100 feet and 10 feet deep. These depressions are also coincident with "white water" on the photo of the rapids.

On the outside of the bend, erosion produced a subaqueous terrace projecting out about 100 feet from the Sheek Island shore and submerged by about 8-10 feet of water. It is composed of dense till, tightly armored with a layer of boulders on top and front. The boulders range up to 4 or 5 feet in diameter. It was obviously this boulder armor which protected the shore from erosion. Till fabric of the dense blue till of this terrace has a strong maximum from the northeast, showing it to be Malone till.

On the southwest bank, on the inside of the bend, till was also encountered. At water level, and below, the till fabric from the northeast shows it to be Malone till, whereas the upper part of the bluff and hills has a northwest fabric and is therefore Fort Covington till. At cofferdam "E" borrow pit, on the north slope of the Long Sault Island, 6 to 8 feet of Lake Fort Ann varved clays lie on Fort Covington till. These varved clays descend the slope of the till and occur as a 5-foot-thick deposit, whose top is at least 6 feet below the old river level. They must have been in a protected cove along the bank of the river.

These observations show that the river followed a "first order" northeast-southwest depression, and then turned to follow a "second order" depression across the west end of Barnhart Island. The river easily cleared out the lake varves, the marine clay, and the soft Fort Covington till. It then cut through the Malone till in its main channel down to bedrock, and left patches of this tough till as boulder-armored subaqueous terraces along the sides of the main current.

Potsdam Quadrangle

The Potsdam quadrangle, lying south of the Massena quadrangle, slopes from the Adirondack Precambrian upland standing over 1,000 feet in altitude in the southern half of the quadrangle, to the drive-covered Paleozoic Lowland at 400 feet in the north. The Precambrian upland is covered with thin discontinuous drift, with kame terraces in many of the valleys. The lowland exhibits the characteristic northeast-to-southwest trending till ridges of the Fort Covington Moraine. This moraine, as elsewhere, has been washed by Champlain Sea waves which subdued it and littered its higher parts with winnowed till, and beach ridges filled its lowlands with clay, silt, and sand. A lobe of this ice projected south into Raquette River Lowland to deposit the end moraine topography as far as West Parishville and the large kame field from Stafford Corners to Brown's Bridge.

South of the margin of the Fort Covington drift, and east of the Raquette River, Malone till is exposed in roadcuts at the following localities:

1. 1 mile east of West Parishville
2. Hayes School, 1 mile east of West Stockholm
3. ½ mile east of Buckton
4. 3¾ miles northeast of Parishville
5. Allen Falls
6. At western edge of quadrangle, 3 miles southwest of Colton

These all show the typical red-brown color of the Malone till. Two of them—3 and 4—where till-fabric studies were made (Appendix I-E), show emplacement from the northeast. This drift is leached to a depth of 5½ feet. The two major kame fields associated with this drift sheet, south and southwest of Parishville are leached to a depth of 6 feet.

Major pebbly sand shore line deposits are found in the central and northern part of the quadrangle. As mapped by Reed (1934) after Fairchild (1919), a sandy shore terrace, with flattish top at 900-920 foot elevation, trends northeast-southwest through Parishville where the West Branch St. Regis River built a considerable delta, to Colton where the Raquette River likewise built a deltaic mass of sandy material with top at 920 feet. Both delta masses are now deeply trenched by the rivers and dissected by tributaries. One of the most striking phenomena is that the Raquette River Delta, 2 miles south of Colton, is extensively pitted with ice-block depressions. Fairchild attributed this 900 foot shore line to his Lake Iroquois. Lower deposits of sandy material occur along the rivers. Along the Raquette River in the vicinity of Hannawa Falls an extensive flat-topped deposit slopes gently northward from about 575 feet near Brown's Bridge down to about 540 feet 1½ miles north of Hannawa Falls, where it drops in a steep "delta front" down to about 480 feet. The deltaic deposits at about 575 feet may belong to the Champlain Sea.

Waddington Quadrangle

The Waddington quadrangle, which lies west of the Massena quadrangle, is likewise a low-lying area of northeast-southwest mounds of till, separated by flat lowlands containing clay capped with sand. Grass

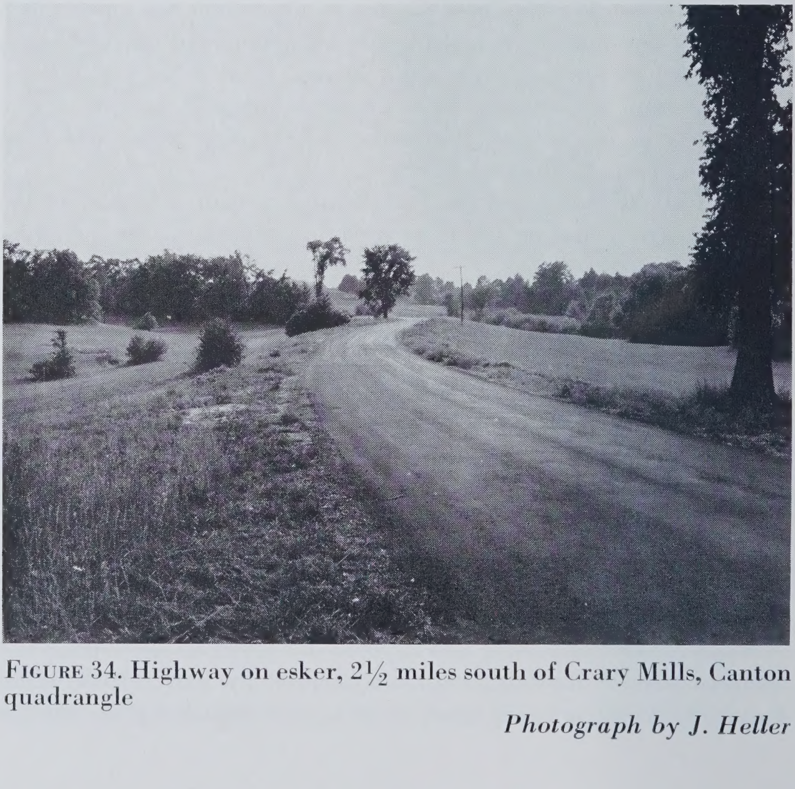

FIGURE 34. Highway on esker, 2½ miles south of Crary Mills, Canton quadrangle

Photograph by J. Heller

River traverses the center of the quadrangle and Sucker, Brady, and Coles Brooks drain the northwestern part into the St. Lawrence, which flows northeast across the upper part. Like the Massena area, this one has been washed by Champlain Sea waves and littered with fossiliferous winnowed till on crests of most of the hills. Such boulder-strewn beaches are strikingly developed a mile northeast and a mile south of Louisville, a mile northeast of Chase Mills at Madrid, and a mile northeast of Madrid. The clay in the lowlands is found to contain fossils at 3 miles south-southeast of Waddington and 2½ miles northeast of Waddington, along the banks of the St. Lawrence River. The silty clay of the lowlands, as mentioned before, is mantled with a few feet of fine sand. This sand has been blown into dune areas, some of which are a mile or so in extent, such as seen south of Chase Mills and east of Chamberlain. It is therefore inferred that Malone till covers the Waddington area, and is overlain by Fort Covington till. This latter has been washed by Lake Vermont waters and subsequently by Champlain Sea.

The valley of Coles Creek, 3½ miles east of Waddington, is too large and swampy to have been cut by the present insignificant trickle of water. Likewise it is partly blocked by alluvial fans deposited at the mouths of tributary gullies. These phenomena are compatible with the hypothesis that this was the former course of Grass River, before diversion by uplift or capture toward the east.

Canton Quadrangle

The southern part of Canton quadrangle lies in the Adirondack Precambrian upland plateau rising in altitude from 600 or 700 feet up to 1,200 feet, and gently dissected by preglacial Grass River and its tributaries into mature rolling upland, with the main stream in a 300-foot-deep valley. The northern half of the Canton quadrangle lies in the St. Lawrence Lowland, where virtually horizontal Paleozoic rocks have insignificant relief below the mantle of the glacial drift.

Boundary of Fort Covington Drift

The line between Paleozoic and Precambrian bedrock approximately coincides with a line of distinction between the two types of till. To the south of this line, the till has the distinctive red-brown color and its till fabric shows it to have been emplaced from the northeast. A good exposure of the red-brown till is seen in the roadcut 3 miles southeast of Canton (Appendix I-D). The cut exposes 15 feet of dense silty till with characteristic red-brown color. It is leached of lime to a depth of 4-4½ feet. A second good exposure of the red-brown till is seen at Brick Chapel, ½ mile to the east. A third occurrence lies south and southeast of Pierrepont at the southeast edge of the map, along the new road to Colton; also, half a mile north of Beach Plains Church, red-brown till is seen in the roadcuts.

To the north of the boundary of the Fort Covington till, the till is slate-gray, weathering to buff, and the till-fabric analysis shows it to have come to its present location from the northwest.

Striae

On the northeastern outskirts of Canton, on both sides of Judson Street, ice-scoured and rounded outcrops of granite gneiss show, by striae and rows of both parabolic tension cracks and lunar shear-cracks (friction cracks of Harris, 1943) that ice came first from the northeast and later from the northwest. Similar relations were described earlier, as seen on limestone in the quarry at Norfolk, 15 miles northeast of Canton, where 20 feet of gray-buff till overburden have been stripped in the quarry operation. Here, N 20°W striae descend into and across N 65°E glacial grooves. Till fabric of the buff till, as measured in the exposure at the southeast edge of the campus at St. Lawrence University in Canton, shows emplacement from the northwest (Appendix I-U). The till here is leached to a depth of 2 feet. A second good exposure was seen in 1955 in a warehouse foundation excavation 2 miles west of Potsdam, near the edge of the Canton map (Appendix I-L). The Fort Covington gray-buff till in the northern part of the Canton quadrangle occurs in roughly northeast-southwest ridges, each about 1 to 3 miles in length and a mile or so in width. The original morainal topography, as left by the Fort Covington ice, has been greatly subdued or completely destroyed by the wave work of the Champlain Sea, as seen in the deposits of winnowed till which surmount most of the higher till ridges in the northern half of the quadrangle. This winnowed till, as has been said, is composed of the coarser stones, pebbles, and sand of the till after the clay, silt, and fine sand fractions have been removed by wave action and washed down into the lowlands. In the northern part of the quadrangle, fossil shells of *Hiatella* and *Macoma* have been found in three gravel pits in the winnowed till: (1) 2 miles north of West Potsdam, altitude 380-400 feet; (2) 3 miles west of Norwood, altitude 340 feet; (3) 2½ miles southwest of Norwood, altitude 380 feet.

Esker

A ridge of gravel 2¼ miles northeast of Canton is about 30 feet high and ¼ mile long. It trends N 40°W, is composed of mounds of gravel, and occupies the axis of a gentle north-south depression between two hills of till. Since it is associated closely with the buff till of the Fort Covington drift, it seems best to map it as a small eskerine ridge modified by Champlain Sea waves. Chadwick (1920) also describes an esker 1½ miles southwest of Crary Mills (figure 34), which lies along Boyden Brook and across the Fort Covington Moraine.

Beach Ridges

Four smaller hills that surmount the large northeast-southwest ridge of till a mile east of Morley are composed of winnowed till. As seen on the floor of the gravel pit northeast of Morley, this winnowed till, about 10 feet thick, lies on fairly dense buff till. The winnowed till blanket has been heaped into northeast-southwest beach ridges 5 to 10 feet high, parallel with the main ridge, and makes a descending flight of small parallel ridges down the northern flank of the main hill. The winnowed till beach ridges at the northeast end of the main ridge are likewise oriented northeast, whereas the ridges at the southwest end of the main ridge are oriented north-south, and may be spits or hooks of the ancient shore. The altitude of the beach ridges descends from about 420 feet down to about 360. Even though the highest marine shells in the Canton quadrangle, as previously mentioned, were seen in the gravel pit 2 miles south of Norwood at altitude 380 feet, the ridges are all attributed to the Champlain Sea, and the descending sequence of these beach ridges shows that they were formed as the hills progressively emerged from the sea.

The middle and lower slopes of the large northeast-southwest hills display only till. It is a washed-off surface, here and there littered with boulders, across which the finer material has been swept from the hilltops into the lowlands. In the army engineer test borings at Richards Landing, the presence of a 6-inch layer of gravel in the clay sequence suggests the presence of turbidity currents moving into the basins of the muddy Champlain Sea floor.

Topographic Expression of the Till of the Canton Area

The "washed-off till," as previously described, shows a surface which is entirely till, with boulders lying on top, so that an auger hole put down between the boulders encounters till at a few inches below the sod. The topography may still show semblance of roundish mounds and hollows as remnants of morainal topography.

The winnowed till or "washed-out" till, also may have boulders scattered on the surface, but the auger does not reach till between the boulders, only sandy stony material virtually impossible to drill into. The microterrain on the surface, furthermore, is made of low, elongate, parallel ridges a few feet high by several hundred feet long and parallel to the trend of the main hill. Where excavations have been made to obtain gravel for the local roads, it is seen that the blanket of winnowed or "washed-out" till forms a cap on the hilltops and has been piled into beach ridges or storm beaches. So characteristic are these beach ridges that they have been used as a diagnostic criterion in mapping the areas of winnowed till.

Fossil shells are also found in the silty clay deposits of the lowlands. A mile north of West Potsdam, a roadcut in the low terrace of Trout Brook shows fossils in the silty clay and in sand at elevation of 340 feet. Both *Hiatella* and *Macoma* are present. Half a mile north of Bucks Bridge, in the terrace along Line Creek at an altitude of about 300 feet, the rivercut in the terrace exposes about 20 feet of silty clay. *Macoma* shells occur in abundance in the upper part, whereas only the impressions of large *Unio* shells were found in the lower 3 or 4 feet. This suggests that fresh-water conditions preceded marine-water environment. The same conclusion comes from two other exposures in the Canton area: (1) 1 mile northwest of Canton a borrow pit in the lowland terrace exposes this sequence: 4 feet of sand, on 8 feet of structureless clay, on 2 feet of varved silt and clay, on buff till (the varved clay is from a fresh-water lake, and the structureless clay is marine) ; (2) at the junction of Grannis Brook and Boyden Brook 4½ miles east of Canton, 12 feet of fresh-water varved clay lie on buff till and below about 10 feet of structureless gray clay capped with a few feet of sand. The sporadic distribution here of the clays along the valley sides shows that the valley of Boyden Brook was a depression in the drift, as left by the Fort Covington Glacier, and was partly filled by lake sediments capped by marine, silty clay and sand. Subsequently, these latter two sediments were eroded out by the streams, leaving the clays here and there along the valley sides, which are elsewhere composed of till. Throughout the whole St. Lawrence Lowland, clay and silt deposited in the lower places in the glacial drift topography have been subsequently trenched, and in places removed, by fluvial erosion. Mapping has revealed only a generalized pattern of irregular more or less connected clay and silt-floored lowlands, among roughly northeast-southwest ridges of till. Many exposures of bedrock show that the till is not very thick, and that it occurs mostly as mounds which rise 40 to 60 feet and a few to as much as 100 feet above the surroundings.

Shore Lines

Within the area of the Canton quadrangle, several flat-topped areas of wave-washed pebbly sand record shore lines of former bodies of standing water.

At Pyrites, in the southwest corner of the quadrangle, lies a delta of sand with top at 500 feet in elevation deposited by the Grass River at this level. The highway cut exposes about 60 feet of this sandy deposit. It is fairly well stratified and dips gently to the north. It is evidently the deltaic deposit built by Grass River into a body of standing water. When this body of water disappeared, the Grass River became superimposed in a new valley on to bedrock and made the present water falls and rapids. At Boyden Corners, Boyden Brook has likewise deposited a flat-topped mass of sand as a deltaic deposit at 500 feet altitude. Grannis Brook near Crary Mills, and Little River, just north of North Russell, have deposited similar masses of sand. This shore line, at about 500 feet, correlates with the Champlain marine shore line eastward as far as Covey Hill, where it stands at 525 feet elevation. The pebbly sand patch at Beach Plains Church has been assigned to the waters of Lake Iroquois by former writers.

Chadwick (1920) correctly ascribed to the Champlain Sea the beaches on the hills about Norwood, north of West Potsdam, and east of Morley, and on Morley Ridge. As found in the present survey, winnowed till caps Norwood Hill at 400 feet altitude and hills north of West Potsdam at 400-420 feet, east of Morley at 420-440 feet and Morley Ridge summit at 400-420 feet. Many other deposits of winnowed till blanket the tops of till hills in the northern half of the quadrangle. As mentioned earlier, marine shells are found in this winnowed till to altitudes of 380-400 feet, 4½ miles southwest of Norwood, and 380 feet, 2½ miles south-southwest of Norwood. These altitudes supply a minimum figure for marine deposits. Inasmuch as *Macoma* and *Hiatella* occur in sea water from a few to more than a hundred feet deep, they do not tell us conclusively what the maximum sea level of the time was, and therefore a 500 foot shore line is entirely plausible. In fact, Fairchild (1919b) has published the view that the shore line at 500 feet on the Canton sheet is that of Gilbert Gulf of the Champlain Sea. A striking strand line with sea cliff occurs just south of the Canton quadrangle on the Russell quadrangle, and will here be described.

The northeast-southwest ridge of gravel 2 miles northeast of Crary Mills may be a beach ridge, but the altitude of 580 feet at its summit and the coarseness of its material suggest that it is more probably a frontal kame deposit.

Russell Quadrangle

The Russell quadrangle adjoins the Canton quadrangle at the south. It lies south of the border of the Fort Covington drift sheet, and is an upland area of Precambrian rocks with a gently rolling surface, around 800 feet at the north rising to 1,500 feet at the south, and cut by Grass River drainage in 300-foot-deep valleys. It has been strongly glaciated, which (1) rounded and smoothed bedrock outcrops; (2) littered the area with boulders and thin drift; (3) deposited three areas of red-brown Malone till; and (4) accumulated kame terraces in the major valleys during deglaciation (figure 35).

Malone Till

Striae in many places trend S 10°E to S 10°W. Till fabric shows a northeast maximum. The areas of red-brown Malone till are in the northern part of the quadrangle. One lies just east of Hermon, and is about 1 mile wide east and west by about 3 miles north and south. Good exposures of this till are seen (1) at the northwest end of this patch in a borrow pit excavated into the steep face of the hill, 1½ miles northeast of Hermon; (2) along a roadcut a mile southeast of Hermon, where the till fabric maximum is from the northeast (Appendix I-F) and leaching is 5½ feet deep; and (3) along the road ½ mile northwest of Hermon at elevation 420. A second and larger tract about 2 miles square occupies the flattish upland in the north center of the Russell quadrangle, 3 miles east of Hermon and 3 miles north of Russell. It is also composed of calcareous till leached to a depth of 5 to 6 feet, and has till fabric showing

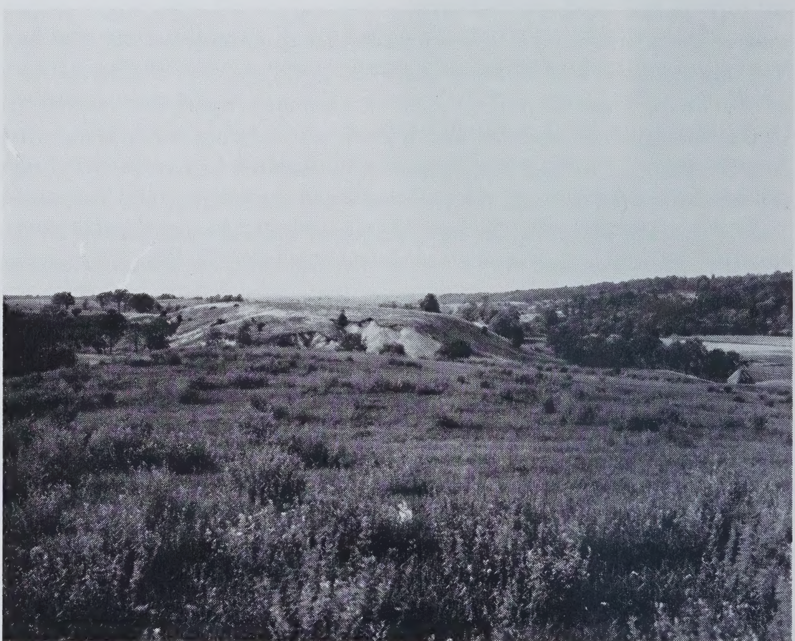

FIGURE 35. Kame terrace in Plumb Brook Valley at South Russell, Russell quadrangle

Photograph by J. Heller

orientation from the northeast. The third patch of Malone till forms the flat upland tract at the western end of Hamilton Hill, 2 miles southwest of Russell. No exposure was found deep enough to test its depth of leaching or till fabric, but because it is red-brown in color, it probably belongs to the same till sheet as the others.

Kame Terraces

Kame terraces lie along the flanks of many valleys. Along the east margin of Elm Creek Valley extends a kame terrace and belt of kames. It is about 1 mile wide and 7 miles long, from Stalbird almost to South Edwards. The gravel of this area is dominantly composed of Precambrian rocks, including abundant marble from the northwest. It is leached cariously from 2 to 5 or 6 feet at different places.

The Russell quadrangle contains, in addition to the Elm Creek kame terrace, several other areas of kame terraces: (1) An east-west kame terrace area occurs along the north slope of Backus and Blanchard Hill, 1½ miles southeast of Russell; it measures ½ mile wide by 2½ miles long. (2) Plumb Brook Valley is flanked for 3½ miles by kame terrace deposits of sand and gravel (figure 35). This material is leached of its lime to a depth of 6 feet, except on steep slopes where erosion has kept pace with leaching. At many places, the gravels of the kame terrace are overlain by horizontally bedded, lacustrine lake sands and silts between 760 and 800 feet altitude. Along the highway ½ mile southeast of Whippoorwill Corners, varved silts and clays of the lake episode are folded by subaqueous slumping as ice blocks melted out from the kame terrace. This relationship shows that the lake followed shortly after the waning of the glacier, before ice blocks had melted out of the kame terrace gravels. This lake therefore would be early post-Malone in age. (3) There are several small kame terraces in the neighborhood of Monterey de Grasse leached to a depth of 6-7 feet, except 3 feet at the top of a very sharp knoll ¾ mile northwest of South Russell, and are assigned to the same episode of glaciation as the red-brown Malone till. (4) In the southwestern corner of the quadrangle south of Pond Settlement lies a square mile or more of flat-topped, pitted, kame gravel. Many undrained depressions, two of which contain lakes, attest to the presence of buried ice blocks when the feature was made. Leaching again varies from only 1½ feet at hilltops to 3-4 feet on flats, and suggests that it is a continuation of the Elm Creek Moraine of Fort Covington age. (5) Kame terraces occupy Van Rensselaer Valley in the northeast part of the quadrangle near West Pierrepont. The gravel is leached to a depth of 6 feet below the flattish top of the kame terrace, and is assigned to the Malone episode.

Hermon Region

At Hermon, Elm Creek flows over bedrock in a rapid descent from the flat river bottom, at altitude 495 feet, down to the grade of the Grass River 4½ miles to the northeast, at an elevation of 360 feet. This drop of 135 feet takes place mostly in the northern part of the village of Hermon. Upstream from Hermon, the bottom of Elm Creek Valley is graded from 495 feet at Hermon to 580 feet at the south, a distance of about 7 miles. Therefore, in the northern part of Hermon village is a major drop from the graded condition to the south into the much-dissected valley lowland to the north. The valley of Elm Creek, north of Hermon, is flanked by silt and sand fluvially dissected into sharp gully and hill topography. At first glance it resembles ice-contact topography, but there are no stones, cobbles, till, or gravel, and no undrained depressions. The whole slope is fluvial topography; every depression seen could have been made by flowing water, and every hill could have been left by fluvial cutting of the adjacent or surrounding depressions. It is apparent that the capacious valley depression north of Hermon was once filled by sand and silt up to the 500 foot level, and has been excavated to its present topography by fluvial erosion. Fairchild was correct that Elm Creek entered a body of standing water at 500 feet, present elevation. It graded its valley above that level, and filled the lowland up to this same level, i.e., 500 to 520 feet.

Two miles north-northeast of Hermon, at elevation 520 feet, the northwest slope of the large till hill which rises at its top to 620 feet exhibits a well-developed beach, consisting of a sea cliff, a boulder, and cobble-strewn beach, and a pebbly sand shore terrace. This strand line is horizontal. The sea cliff, or bluff, is about 60-75 feet high, and is composed of calcareous red-brown till leached 5 feet. It is dissected by large gullies about 20 feet deep by 200 feet across, cut into steeply sloping shore bluff of the ancient water body. These gullies end completely at the old strand line, without any alluvial fans at their lower ends, where there is just a horizontal terracelike shelf littered with cobbles and boulders (figure 36). This boulder-strewn beach circles the northwest slope of the hill, precisely where it could have been most exposed to the attack of waves from the northwest where strong winds and long fetch would have been most effective. To the northwest from the boulder beach, lies a pebbly sand terrace, now dissected by gullies 50 feet deep. On the lower slopes of these gullies clay and silty clay are encountered.

This pebbly sand and clay terrace is continuous with the pebbly sand terrace deposit of the Pyrites region, where the Grass River descends to the 500 foot level, and a terracelike deposit of pebbly sand flanks the northeast slope of the uplands.

Evidence in the Hermon-Pyrites region demonstrates former existence of a body of standing water at present elevation of 500-525 feet near the St. Lawrence River. Where gradients of tributary valleys are fairly low, dissection of the Champlain silt and clay deposits has progressed until systems of dendritic gullies have fairly well cut up some of the lowlands. With this as a comparison, it is easy to imagine post-Champlain fluvial erosion on the steep gradients of the Hermon region, dissecting at an even greater rate in the sandy-silty deposits. In 1955, a bit of very rapid erosion was seen in the ancient sandy, silty delta of the Oswegatchie River in the southwestern part of the Russell quadrangle. About 1/4 mile south of the Hermon school a gully is cutting headward into the western flank of this flat-topped delta mass. It is about 60 to 80 feet deep, steep-sided with vertical box-canyonlike head. It is already 1/10 mile long, and growing 50 to 100 feet with every big rain. In a few hundred years it will have dissected this whole part of the delta. By seeing the speed of gully growth in this sandy material, it is easy to picture how these deposits were cut up by rainfall while they were bare of vegetation in the geologic past.

Since no fossils have come to light in the Hermon region, evidence is not at hand to specify whether or not the body of standing water at 500-520 feet was a lake or the Champlain Sea. It can only be said that water must have stood at this level for a considerable length of time to have produced the deltaic and shore line feature as now seen.

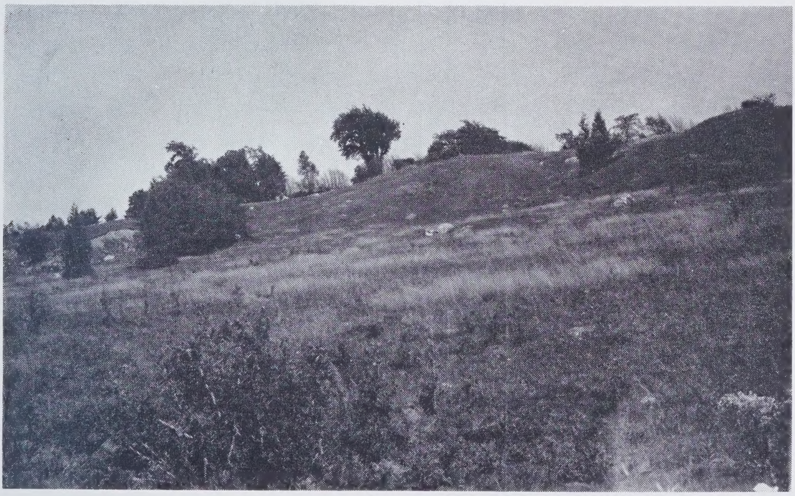

FIGURE 36. Gullies ending at the strand of the Champlain Sea at altitude of 520 feet, 2 miles north-northeast of Hermon, Russell quadrangle

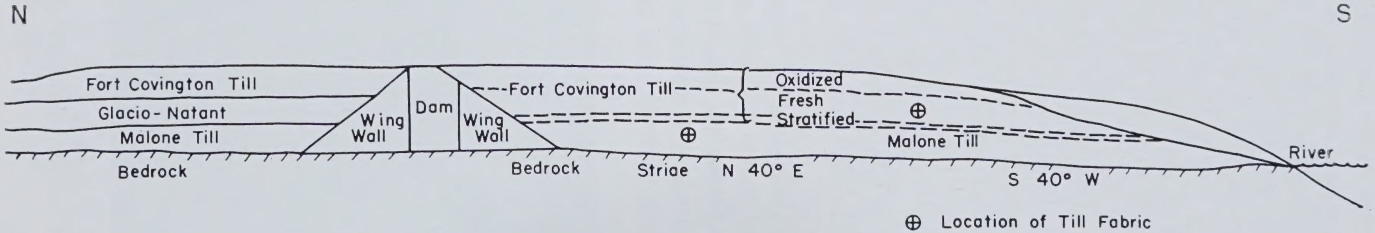
N
S
Fort Covington Till
Glacio-Natant
Malone Till
Bedrock
Wing Wall
Dam
Wing Wall
Fort Covington Till
Oxidized
Fresh
Stratified
⊕
⊕
Malone Till
River
Bedrock
Striae N 40° E
S 40° W
⊕ Location of Till Fabric

FIGURE 37. Diagram of Iroquois Dam excavation, east face

Red Mills Quadrangle

Only the small southeast corner of the quadrangle lies in the United States and has been mapped for this report. It, like the adjacent areas, is made of northeast-southwest till hills surmounted by winnowed till beach ridges, and surrounded by marine clay and sand. Two miles east of Rockaway Point, a small gully reveals dark, drab-gray clay lying on buff oxidized till. No leaching is seen at the contact, but the rusty color of the till below dark clay suggests either (1) that there was some surface weathering of the till before deposition of clay, or (2) that oxidizing solutions have penetrated the clay and affected the till more than clay, or (3) that subterranean staining of the till has been accomplished. This phenomenon is described here because it is a widely encountered occurrence in both the St. Lawrence and the Champlain Valleys.

In the Red Mills quadrangle, several excavations for the seaway have uncovered Pleistocene phenomena of significance.

Iroquois Dam

Excavation into Rockaway Point for the east abutment of the Iroquois Dam went down through a hundred feet or more of drift, and laid bare about an acre of beautifully striated limestone bedrock. The striae trend S 40°W. The bedrock is overlain by two sheets of till, separated by a layer of characteristic glaciolacustrine drift. This latter is stratified and composed of sand, clay, and silt. In places it is crammed with stony to bouldery glacial material. The lower till has fabric from the northeast, whereas the upper till has fabric from the northwest. The lower till is therefore the Malone till, and the upper is the Fort Covington. The presence of the berg-rafted lake sediment between the two tills indicates that the Malone ice waned by calving into a lake, prior to the advance of Fort Covington ice.

At the northern end of the excavation, as exposed in 1955, 10 feet of fossiliferous marine clay is seen to lie on about 10 feet of good varved silt and clay, which in turn rested on buff calcareous Fort Covington till. This is one of the many typical exposures which show that a lake followed the Fort Covington episode, and varves as well as till were both exposed to surface oxidation prior to the marine invasion. Along the cut for the access road at the south end of the excavation, fossiliferous marine clay in places lies directly on buff till; the latter becomes blue-gray at base of exposure. Not only does the clay lie directly on till, but it is seen to lie in small hollows more than 10 feet deep in the surface of the till. At several places, till from tops of the little hillocks is seen to have slumped or moved out over some of the fossiliferous clay in adjacent depressions.

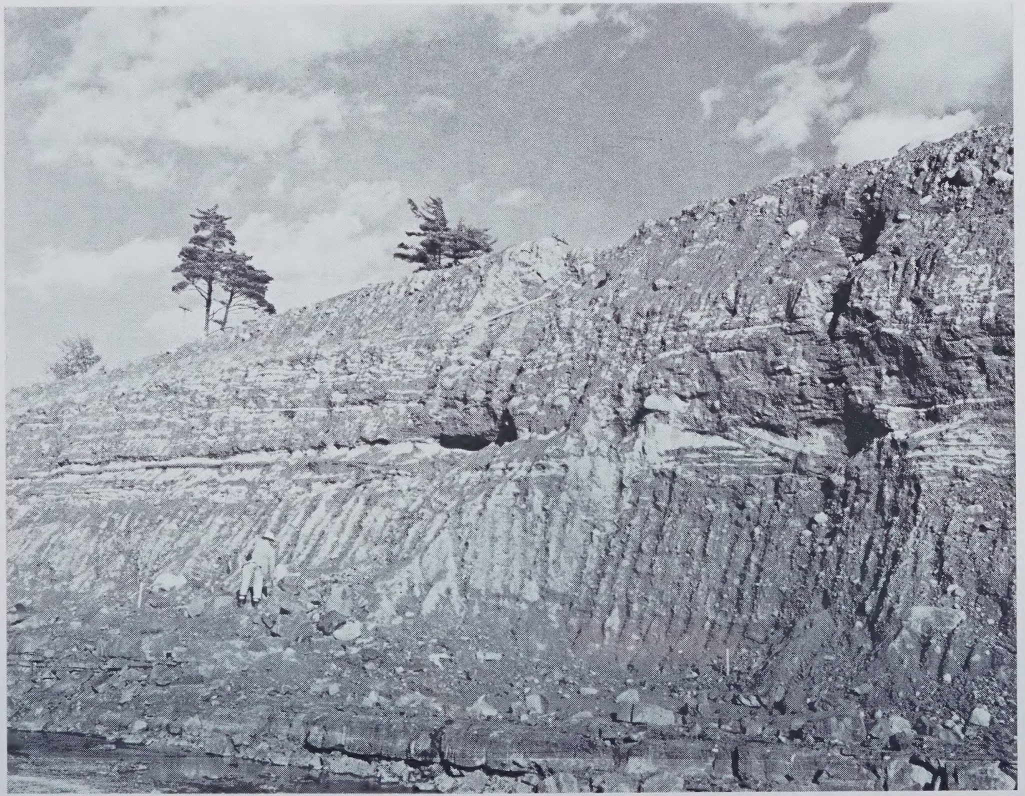

FIGURE 38. South wall of Iroquois lock excavation, showing bedrock, Lower Malone till, and Middle till complex

Photograph G. W. Brownell, Ontario Hydroelectric Development Corporation

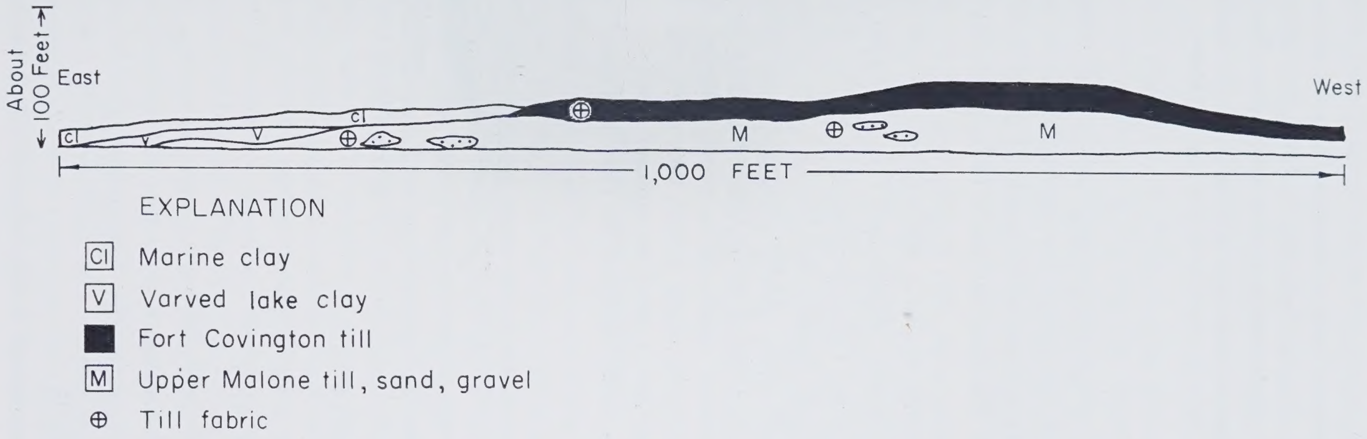
About 100 Feet
East
West
Cl
V
cl
M
M
1,000 FEET
EXPLANATION
Cl Marine clay
V Varved lake clay
Fort Covington till
M Upper Malone till, sand, gravel
⊕ Till fabric

FIGURE 39. Point-Three-Points, inland bank, toward the south

This has produced till on top of fossiliferous clay, which would certainly be confusing if encountered in a boring sample, as has undoubtedly been done in some of the seaway explorations. These exposures, which unfortunately have been destroyed by further excavation, illustrate that the Fort Covington till had a morainal topography which was modified first by lake waters and then by marine waves and currents.

Iroquois Lock

On the north side of the St. Lawrence, across from Rockaway Point, the Iroquois Point was cut through for construction of the Iroquois lock. The cut goes down through two tills separated by a thick layer of stratified material (figure 38). The lower till lies on bedrock striated N 40°E. The stratified zone contains sands, silts, gravels, and in many places masses of material studded with boulders and cobbles, just like the obviously ice-rafted material between Malone and Fort Covington till across at Iroquois Dam excavation. Fabric analysis showed also that the two tills at Iroquois lock are the Malone and the Fort Covington, respectively (Appendix I-VV, WW, FFF). At one level in the stratified material, a layer of silt is seen in a bed of sand. The sand shows that the silt was deposited on symmetrical ripple marks about 6 inches from crest to crest. If they are in reality ripple marks, they show a good-sized body of open water, rather than a small ice-dammed pond.

Excavation of the south shore of the river at Point-Three-Points, a

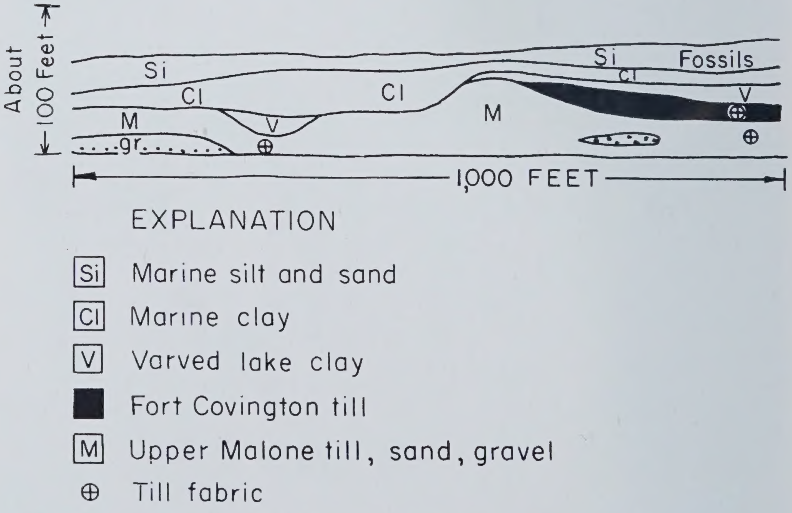
About 100 Feet
Si
Si
Fossils
Cl
Cl
Cl
M
M
V
V
gr.
1,000 FEET
EXPLANATION
Si Marine silt and sand
Cl Marine clay
V Varved lake clay
Fort Covington till
M Upper Malone till, sand, gravel
⊕ Till fabric

FIGURE 40. Sparrowhawk Point, inland bank, toward the south

mile east of Rockaway Point, reveals Fort Covington till lying on the upper Malone till, sand, and gravel complex. At the eastern part of the exposure, varved clays occur between Malone drift and marine clay (figure 39), but the clay also rests on Malone drift, showing that varved clays were either not deposited or were eroded away before the marine invasion.

Excavation of Sparrowhawk Point, 3 miles west of Rockaway Point, exposes the drifts as shown in the diagram (figure 40), where again Fort Covington till lies on Malone drift in the western part of the exposure, covered by lake varves and marine clay and silt. In the eastern part, however, varved clay and marine sediments rest on Malone drift. Varves were either not deposited or were eroded prior to the marine invasion.

Six miles west of Iroquois Dam, a cut for channel improvement is excavated through Gallop Island. It exposes bedrock striated N 40°E, on which lies only thin patches of till. Elsewhere varved and glacionatant stratified and stony material lies on bedrock; one boulder is of especial interest in this exposure. It is an 8- or 9-foot well-rounded boulder of tillite resembling the Goganda or Cobalt tillite, and could have gotten here only by ice movement from the northwest toward the southeast, i.e., Fort Covington glaciation.

Ogdensburg Quadrangle

The Ogdensburg quadrangle lies next west of the Canton quadrangle. For the most part, like the previously described areas, it comprises till, ridged in northeast-southwest orientation, with marine clay and sand in the lowlands, all lying on Paleozoic bedrock. In the southwestern third of the quadrangle, thin discontinuous drift lies on Paleozoic bedrock, and in the southeastern third on Precambrian rock. Cushing (1916) correctly described the drift in the northern part of the quadrangle as a moraine greatly subdued by postglacial waters. His map shows striae trending south to south-southeast, normal to the till ridges. Unfortunately, he confused the issue by calling the conspicuous hill, Mount Lona, 2 miles south of Heuvelton, a drumlin. This hill is one of the most conspicuous topographic features of the whole St. Lawrence Lowland, rising 150 feet from surrounding flats at 320 feet altitude to a summit at 470 feet elevation. Roadcuts and well records show it to be composed of till, with kame gravel at its western end. Till fabric at the eastern end of Mount Lona has a maximum from the northwest showing its surface, at least, to be composed of Fort Covington till (Appendix I-P). The top of this hill is bumpy and irregular like a frontal morainic ridge, which this appears to be. As pointed out earlier, the waters of Lake Fort Ann and the Champlain Sea have washed and subdued the morainal topography. This is seen especially in the subdued topography both to the east and the west of Mount Lona. A group of four small, strikingly parallel, till ridges about 1/4 mile long and about 25 feet high are oriented north-south. They seem to be a group of little drumlins, like those just east of Massena formed during Fort Covington time. In the south-central part of the Ogdensburg quadrangle, about 2 miles west of Coopers Falls, two 20-foot exposures of varved clays are seen along the roads. In the northern half of the quadrangle, the hilltops are capped with deposits of winnowed till gravel, many of which contain marine shells. The altitudes are around 360-376 feet.

Gouverneur Quadrangle

The Gouverneur quadrangle lies south of the Ogdensburg and west of the Russell quadrangles. Its altitude rises from about 400 feet at the north to about 800 feet at the south. It is part of the Frontenac axis, and displays the characteristic northeast-southwest "grain" of outcrops and topography. Fluvial and glacial erosion have produced in this quadrangle a striking example of the intimate relation of topography to lithology. One of the best illustrations is seen at Moss Ridge, 2 miles east of Richville in the central part of the area, where a hook-shaped granite sheet stands now as an 80-foot ridge. Drift is thin or absent over the ridges and only thin, if present, as shown by well records, in the depressions. The depressions are largely floored by clay and silt deposits, many of which are now covered with peat and muck. The clay and silt is mapped only in the larger depressions. Conspicuous glacial deposits are very few. A mass of kame gravel is seen 3 miles southwest of Gouverneur. It is the eastern end of the area of kame gravel that Taylor (1924) called the Gouverneur Moraine. One mile northeast of Gouverneur is a second area of kame gravel, now being actively excavated for gravel and thus exposing many good vertical sections to study. The gravel is leached to a depth of 18 inches. A mass of varved clay is seen to be infolded with the frontal kame gravels, evidently by contemporaneous subaqueous slumping in the waters of the lake into which the kame was being built. Large masses of the varved sediment are seen 15-20 feet below the surface. Four patches of buff till are found in the quadrangle. One is at De Kalb, at the north edge of the sheet; a second just north of East De Kalb displays gentle terminal moraine topography. The third mass is in a north-south drumlin at Kents Corners, near the eastern edge of the map. A 10-foot-deep dug well exposes buff till, with fabric maximum

N 30°W in Fort Covington till (Appendix I-X). The fourth patch of till is a roadcut 1½ miles southwest of Edwards; the northwest maximum of fabric shows this also to be Fort Covington till (Appendix I-Y).

The whole Gouverneur quadrangle therefore was overrun by Fort Covington ice, whose margin lay to the east and south of the quadrangle. The silty clays of the lowlands are seen to be varved near Maple Ridge School at the north, near Edwards at the east, and near Hailesboro in the western part of the area. These examples show the wide distribution of lake sediments over the area. In the south-central part of the area, with its center at Fullerville Ironworks, is an extensive Lake Fort Ann deltaic deposit of pebbly sand, whose surface rises southward from about 700 feet near the Oswegatchie River to about 780 feet at the south margin of the quadrangle, and to 800 feet in the northern part of the Lake Bonapart quadrangle, where it is pitted by the melting out of buried ice blocks. The basins of the several lakes may have been occupied by ice blocks, or may be the result of solution of marble bedrock.

Brier Hill Quadrangle

The Brier Hill quadrangle lies to the west of the Ogdensburg quadrangle. Although slightly more than one half of this quadrangle lies across the St. Lawrence River in Canada, the southeastern part, in the State of New York, is a most significant area. The boundary between the Fort Covington till to the east and the area of glacial retreat by calving crosses this area. It is also near Ogdensburg that the westernmost fossils of the Champlain Sea in the United States are found.

An area of Fort Covington Moraine is the only till deposit mapped in this quadrangle. This till accumulation marks the boundary (north of the Frontenac axis) between the tableland topography and the massive till moraines which characterize the topography to the east.

The southwestern end of the moraine, in the latitude of Morristown, has two prongs: One starts in the town of Morristown, near the St. Lawrence River, and the other begins along Black Lake, 1 mile southwest of the northeast corner of the Hammond quadrangle. The two prongs converge near the head of Chippewa Creek, 4½ miles east of Morristown. From the point of convergence the moraine trends northeastward to the boundary of the Brier Hill quadrangle, covering most of the surface between the lake and the river in this area. The till composing the moraine is not of great thickness, and much of the relief is due to a bedrock core. The topography is definitely that of a moraine, however, and ice front characteristics can be observed. The surface of the moraine is quite bouldery, indicating that the surface has been washed by waves, and in many areas the wave action has greatly subdued the topography. The till is bouldery and sandy, with rather low amounts of clay and silt.

Brier Hill Kame Terrace

The northeastern end of a stratified gravel deposit, designated in this report as the Brier Hill kame terrace, lies within the village limits of Brier Hill. From this locality the deposit trends southwestward for a distance of 4 miles, along the northwestern wall of the valley containing Chippewa Creek. In this area, the Theresa dolomite and Potsdam sandstone form almost vertical walls, approximately 100 feet high, along the north side of the valley. The gravel terrace laps high on the valley wall, and in some places completely covers it, and slopes gently into the valley. The kame terrace averages about one-half mile in width, but widens to over three-quarters of a mile in the vicinity of Chippewa Creek Church. Except for a slight dip away from the valley wall escarpment, the stratification in the gravel is essentially horizontal.

The surface of the terrace is covered by a thin veneer of fine lacustrine sand that extends out into the floor of the valley, beyond the limits of the gravel. Where Chippewa Creek has cut through the gravel composing the terrace, lacustrine clayey silts and silty clays are exposed on the banks of the stream, indicating that the whole terrace is probably underlain by lake sediments.

Three gravel pits, now in operation, offered good exposures of the gravel composing the kame terrace. The easternmost of these lies on the western edge of the village of Brier Hill, and the other two are 1¾ miles southwest of the village. The westernmost of these pits shows an exposure approximately 80 feet high. The gravel studied in these openings is clean and of rather uniform texture, usually ranging from medium sand to medium cobbles, with larger boulders in varying numbers occurring irregularly in various sections. A large reserve of good-grade gravel is available in this deposit.

Closely associated with the kame terrace is a kame moraine which extends northward from Chippewa Creek Church for a distance of 2 miles. There are no gravel pits now in operation in this moraine, but outcrops were found in a few old workings and roadcuts. The gravel seems to be of good quality, but the exposures studied reveal mostly medium to coarse-grained sand, and only small amounts of cobbles and boulders. Bedrock outcropping along the sides of the kame moraine suggest that much of it has a rock core, and it is therefore impossible to estimate the gravel reserve. The surface of the kame moraine is covered by a relatively thick deposit of lacustrine sand which, in most cases, masks the underlying gravel.

Marine Deposits

An occurrence of marine fossils is located 2.4 miles south-southwest of the New York Central Railroad Station in Ogdensburg. This location is three-quarters of a mile west of the eastern boundary of the Brier Hill sheet and 1½ miles due south of the Pythian Home, located one-half mile southwest of Ogdensburg, on New York Route 37.

The gravel in the deposit forms a small knoll, one-half mile wide and three-quarters of a mile long, that rises 20 to 30 feet above the 300-foot contour that marks its base. The gravel is winnowed till, of medium texture with larger cobbles and boulders dispersed throughout. At the time of this survey, the gravel was being used for roadbed construction and crushing was necessary to prepare it for this use. Occasionally, boulders were encountered that were too large to feed through the crusher.

One-half mile west of the deposit described above is Monkey Hill, a small, streamlined moraine whose crest rises above the 360-foot contour. The crest and slope of this hill are quite bouldery and gravelly, giving a surface appearance similar to a kame. Excavations were made for a home on the crest during the time of this survey, and the digging revealed that the bouldery, cobbly, gravelly surface material was about 3 feet thick. Below this veneer was 2 to 3 feet of medium-textured gravel, and below the gravel was till. Low ridges of this material were found on the crest of the moraine, as well as along the slopes. Because of these characteristics, the surface material was mapped as winnowed till.

One mile west of Monkey Hill, an abandoned gravel pit was found in a small knoll at an elevation of 340 feet. The material was slumped and no fossils were found, but the character of the gravel was so similar to that on Monkey Hill that it was also mapped as winnowed till. One mile south of Monkey Hill, a long ridge was mapped trending north-south for a distance of 2 miles to the vicinity of Stone Church. The surface of this ridge was exceedingly bouldery, and the matrix was very sandy. One abandoned pit was studied three-quarters of a mile northeast of Stone Church, and this material was also designated as winnowed till, in spite of the fact that no fossils were found.

The westernmost of the winnowed till deposits were mapped on a moraine that trends southwest from the Ogdensburg Country Club (6½ miles southwest of Ogdensburg, on New York Route 37). A small ridge of the winnowed gravel at elevation 350 feet lies immediately south of Route 37, one-half mile west of the country club. One and one-quarter miles south of the country club at the same elevation a rather large deposit of the same material follows along the north side of Haggart Road, for a distance of 1½ miles. The gravel was studied in one opening in this deposit. The texture of the grains was generally finer and boulders less frequent than in the deposits described above, but evidence of reworking was definitely present. The surface expression of low linear ridges is similar to those on Monkey Hill.

Tableland Topography in the Brier Hill Quadrangle

West of the Fort Covington Moraine, the topography is typical of the tablelands. Much barren rock is exposed, and the lacustrine sediments are seldom more than 8 to 10 feet in thickness. South of Black Lake, the rocks are crystalline and the Frontenac axis topography predominates.

Evidence of Ice Direction

As described earlier in this report, the striations clearly show that the last ice invasion in this area crossed the St. Lawrence River from the north. These striations, plus shear and tension cracks, are most conspicuous in the vicinity of Morristown.

Hammond Quadrangle

The Hammond quadrangle lies south of the Brier Hill and west of the Gouverneur quadrangles. The whole area, with the exception of the extreme northwest corner, lies in the Frontenac axis subsection and is therefore rough and sparsely settled. Several sizeable granitic intrusions are found in the complex of this section, and these form the more massive, higher, and most conspicuous aspects of the topography. Certain other areas are higher than the general topography because they are capped by outliers of flat-lying, more resistant, Potsdam sandstone. Large swamps are common in the river areas, and the most noteworthy of these occupies the Black Lake depression southwest of Black Lake. Several lakes are also found where the softer beds of the Grenville series were gouged out by glacial erosion.

Lacustrine Material

Lacustrine deposits are irregularly distributed in the lower areas throughout the Hammond quadrangle. Distinct shore lines, however, are absent.

In the area of the Frontenac axis, lacustrine sediments, composed mostly of silty clay and usually rather thin, were found in the low areas not occupied by lakes or swamps. The depressions containing the sediments are generally quite small, and it was deemed inadvisable to map them in detail inasmuch as they have little or no geologic significance. For these reasons, only the larger areas of lacustrine deposits were isolated and mapped in the crystalline rock. The areas of lake sediments mapped in the crystalline complex were mostly in valleys now occupied by streams, which include the Indian River, the Oswegatchie River, and tributary streams that flow into them. This description suffices for all of the areas of lacustrine materials mapped south of the Black Lake depression.

Spragueville Kame Moraine

The gravel deposit designated as the Spragueville kame moraine in this report is best developed, most massive, and reaches its greatest height in the vicinity of the village of Spragueville in the southeastern corner of the Hammond quadrangle. From Spragueville, the moraine trends northeastward as a belt of kames and narrow gravel ridges to the western edge of the village of Gouverneur. From Spragueville, the moraine also extends southward into the edge of the Antwerp quadrangle. Buddington (1934, p. 45), using Taylor's name, describes it as an extension of the Philadelphia Moraine several miles to the south. This present survey, however, traced the moraine from Spragueville 2 miles westward along the southern border of the Hammond quadrangle, where it swings southwest and then south into the Antwerp quadrangle.

The Spragueville section of the moraine, described above as highest and most massive, is approximately 3 miles long and trends northeast and southwest from the village of Spragueville. The average width of the deposit is one-half mile, but it is three-quarters of a mile wide immediately southwest of the village. The crest of the moraine is generally 100 feet above the plain to the north, and the high point on the crest, one-half mile east of Spragueville village, rises to an elevation of 630 feet, which is 160 feet higher than the contact of the lake plain two-tenths of a mile to the north. The southern and northwestern margin of the deposit laps upon the slopes of the crystalline rocks of the Frontenac axis complex.

One gravel pit in the Spragueville section is located in the village of Spragueville, where 75 feet of gravel is exposed along the face. The gravel is very clean, well sorted, and contains a good high percentage of crystalline material including marble from the Grenville series. The texture of the gravel varies from sand to coarse cobbles and small boulders. Near the top of the pit face, a layer of clean sand, approximately 20 feet thick, is exposed.

Since the gravel composing this kame area covers the edges of the crystalline rock on the south and west, as stated above, it is not possible to give an accurate estimate of the total gravel reserve in this section. The northern boundary of the kame, however, borders the lake plain and is not believed to be overlying the crystalline complex. From the village of Spragueville northeastward for a distance of 1¼ miles, the moraine rises abruptly from the lake plain and gravel is exposed all the way up the side. It is definitely concluded, therefore, that a very large amount of good, clean gravel is in reserve in this section.

Three abandoned gravel pits were located in the kames and ridges in the northeastern section of this moraine, which begins 1½ miles north-northeast of Spragueville and trends north-northeast from this point to Gouverneur. The composition of the gravel is much the same as that at Spragueville, but the texture is generally coarser and sorting is not as complete. The reserve of gravel, of course, is not as large in this section, and the quality does not compare favorably with that to the south.

The northeastern end of the southwestern section of this moraine lies 1¾ miles due west of Spragueville. This segment of the moraine trends southwest for a distance of 2 miles and then south for 1½ miles. The composition, quality, and texture of this section is much the same as that at Spragueville. The only opening in this locality is along U. S. Route 11, 4 miles north of Antwerp, and the better part of this segment seems to be near where the highway crosses the moraine. It is believed that a fairly large reserve of gravel is available in this area.

Antwerp Quadrangle

The Antwerp quadrangle, located south of the Hammond quadrangle, shows the Frontenac axis topography in the northern and east-central portion, a tongue of tableland topography, extending from the west into the east-central part of the quadrangle, and sands of the Pine Plains in the south. Rising above this plain are massive moraines composed of both till and kame gravel.

Kame Moraines

The tablelands of the Antwerp quadrangle south of Philadelphia are covered in most areas by kame gravel of the Philadelphia kame moraine. The kame surface, however, is generally covered by a thick veneer of lacustrine clay. The kame gravel is at the surface only in the higher portions of the moraine, but the kame and kettle topography is manifested in the undrained depressions on the surface. It is apparent that a chain of kamic ridges starts near Black Creek, 2 miles south of the Indian River, and extends in a northeasterly direction to the Indian River, 1½ miles east of Antwerp. The manifestations of these ridges are in the form of small isolated gravel deposits emerging from the surface of the lake plain. The kames were apparently higher to the northeast, because a more continuous ridge is found in that direction. Evidence seems to prove that these represent kamic deposits that were continuous and may still be; that have a subdued topography either because they were deposited in lake waters or because they were planed off by wave action, or both. Because of their low relief, these features were later covered by lake sediments and the exposures now found, except the higher ridges to the northeast, have been uncovered by recent erosion.

Buddington (1934, p. 35) describes the Philadelphia Moraine as a part of the Spragueville kame moraine of the Hammond quadrangle. This investigation did not, however, bear out such an interpretation. It is the contention of this report that the Spragueville Moraine trends westward along the southern boundary of the Hammond sheet, and then south into the Antwerp quadrangle for a distance of 3½ miles.

A gravel deposit in the southwestern part of the area forms the Natural Bridge esker. This feature trends southwestward from the village of Natural Bridge toward Devoice Corners, and is termed as the Devoice Moraine by Buddington (1934, p. 43). The length of the esker is 3½ miles; Hogback Road, between Natural Bridge and Hasford, follows the crest of the esker for about 1½ miles. The northeastern section of this ridge rises, in places, to heights over 100 feet above the plains on either side of it, and the crest is generally between 800 and 840 feet in elevation. The feature is a typical esker with a wavy skyline and steep sides, but it has a less serpentine trend than do most eskers.

The gravel composing the Natural Bridge esker was presumably carried into the area from the northeast, since it contains a high percentage of crystalline material, including marble from the Grenville series. Its geologic significance, the writer believes, is that it probably gives an indication of the material composing the kame moraines east of Natural Bridge in the Lake Bonaparte 15′ quadrangle. The deposits east of Natural Bridge were not mapped or studied during this survey, but they were noted along New York Route 3, between Natural Bridge and Lake Bonaparte. These, the writer believes, may be a potential source of gravel composed of material similar to that of the esker.

Another large area of kame moraines lies south of the Black River along the southern boundary of the quadrangle, and extends southward into the Copenhagen quadrangle. These deposits include two separate kame moraines. One, to the east, is crossed by the Great Bend-Carthage Road and lies 1 mile west of the Black River. The second, crossed by the Great Bend-Champion Road, is located 1½ miles south of the village of Great Bend. These features have conspicuous relief, but because they are near the Tug Hill Escarpment they may have a bedrock core.

Till Moraines

One of the large accumulations of till in frontal moraines of the Southwestern massive moraine subsection is found in the southeastern corner of the quadrangle. These moraines are composed of a sandy, bouldery till with summits generally above the 800 foot contour, and rising to over 900 feet 1 mile southwest of North Croghan. Most sections of the moraines have rather bold relief, rising 50 to 100 feet above their surroundings. The most conspicuous moraine knolls are Barr and Ward Hills, southwest of Fargo, which have relief of over 150 feet.

The Pine Plains

The Pine Plains form the surface of the southern one-third of the quadrangle. Buddington (1934) described two separate deltas in this region, one of the Black River at 700 feet and a second, of the Indian River, at 800 feet. The higher sand surface in the vicinity of the village of Natural Bridge does not mark a lake level, but was built between and among the till moraines which have prevented the lowering of the surface by subsequent erosion. The moraines also prevented the spreading out of the sand into the lake during its deposition.

Ice Direction

The few striations found on the limestone rock in this quadrangle indicate that the ice movement was in a southerly direction, as also in the two quadrangles to the north. It seems evident, therefore, that the last ice invasion in this latitude was definitely from the north and not toward the southwest, as formerly believed.

Alexandria Bay and Grindstone Quadrangles

The Alexandria Bay quadrangle lies west from the Hammond quadrangle; the southern half of the sheet lies south of the St. Lawrence River in New York. The Grindstone quadrangle lies west of Alexandria Bay, and only the islands in the St. Lawrence River are within the boundary of the State of New York. Since glacial deposits are rare and very thin, bedrock topography dominates the landscape. Crystalline rocks of the Frontenac axis make the topographic features of the mainland, as well as the islands of the river. Bedrock exposures make up over half of the area of the quadrangles, with the remainder covered with a thin veneer of lake sediments. Abundant striae, grooves, and chatter marks cover the surface of horizontal ledges of Potsdam sandstone, with direction about parallel with the St. Lawrence. Although striae were measured from due south to S 60°W, the most common trend was S 10°W to S 30°W. Just south of Redwood, striae are due south but at Goose Bay they are S 40°W. The ice invaded the north but was diverted toward the southwest, possibly by the topography near the St. Lawrence Valley.

Kame Deposits

Two small kame deposits are seen in the Alexandria Bay quadrangle. The first is dome-shaped, $\frac{1}{2}$ mile north of Redwood. It is of good quality gravel, and is believed to contain a rather large reserve of gravel within a small area. The second area of gravel is located $1\frac{1}{2}$ miles due south of Goose Bay settlement, along the shore of Goose Bay. This deposit is a kame terrace, lapping upon the bedrock escarpment that forms the valley wall on the north side of Cranberry Creek. There are two large gravel pits in the terrace. The gravel is clean, with a large percentage of crystalline material. Some parts are quite sandy. A small reserve of good gravel is present, but since bedrock is exposed only near the rim of the escarpment, measurement of volume is only speculation. It is, however, close to water transportation on the St. Lawrence. Fairchild (1910b, p. 153) describes a row of gravelly kames along the north shore of Grindstone Island.

Gravel Wash

A rather large area in the southern part of the Alexandria Bay quadrangle was mapped as gravel wash. The gravel contains a very high content of sand, the pebbles and cobbles are at the most only subrounded, and sorting is very crude. The term gravel wash was used to designate these deposits because it was believed that they were spread out over the area by wave action. This, of course, is also true of beach gravel, but the source of the material might have been a melting ice margin.

It is possible that this material is a type of beach gravel. Fairchild (1910b, p. 139) describes a bar 2 miles southeast of Redwood that is undoubtedly composed of this gravel.

Theresa Quadrangle

The Theresa quadrangle, south of the Alexandria Bay sheet, lies almost entirely within the southwestern tableland subsection. There is a small area of Frontenac axis in the northeast corner, while in the southeast corner there is a small area of massive moraine subsection and the western margin of the Pine Plains subsection.

The major portion of the quadrangle shows tableland topography as already described. Bedrock is exposed on higher ground, with lacustrine sediments covering the lower areas. In many sections, and particularly in the vicinity of Lafargeville, cobbles and boulders are common, dispersed both on and through the lake clays and silts. The greater part of the area is covered with silty clay, except for the sand plain in the vicinity of Theresa.

Theresa Sand Plain

The Theresa sand plain slopes south, and is an example of a lacustrine sand deposit in which the source of the sand was fluvial. This deposit starts in the village of Theresa, and follows down a former stream valley approximately 2 miles in a southwesterly direction. From this latter point, it spreads out to form a large sand plain with a relatively level surface, the main portion of which is about 5 miles long and 2 miles wide. Another deposit lies to the east of the first plain, and follows lower channels into the Indian River Valley. The fluvial bedding of the northeastern part of the deposit, occupying the former stream valley, can be seen immediately north of the cemetery in the village of Theresa, where a sand bank rises over 60 feet above the floor of the Indian River Valley. Cross-bedded deposits were also studied in a sand pit 2 miles southwest of the village. No openings were found, however, where the deposit could be studied south of this point.

The source of the sand seems to have been to the north, and therefore compatible with an hypothesis of transportation by a stream flowing south from a source at the ice front. Such a stream could have followed the present course of the Indian River southward to Theresa, whence it continued southwestward for 2 miles to enter a lake. Sand must have filled a portion of the present Indian River Valley north of Theresa, but this sand has subsequently been removed by the Indian River. The elevation of the lake at that time is indicated by the general level of the sand, which is now near the 400 foot level, and it is assumed that this marks a level of the lake sequence in the Ontario basin.

Beach Gravel

A noteworthy deposit of beach gravel (Fairchild, 1910) occurs along the slopes of Pine Grove Hill, 4 miles northeast of Lafargeville, where a definite wave-cut shore terrace was mapped during the present survey. Here, a terrace marks a level of lake stability at a present elevation of approximately 335 feet, and a beach is built along the south slopes of the kame moraine hill. Three shore terraces were mapped 2 miles southwest of the Pine Grove Hill, the highest of which is at an elevation of 445 feet. It is postulated that this represents the highest shore feature of Gilbert Gulf in this region.

Till Moraine

An area of frontal moraine of the southwestern massive moraines subsection is located between the villages of Black River and Evans Mills. The crests of this moraine lie generally between the 500 and 600 foot contours, and the relief varies from 50 to 100 feet. There is much evidence of wave action on the top of this structure, with a rather level summit in many places. The till composing the moraine is clayey, but the surface is often sandy and gravelly, due to wave action. This moraine formed under the same conditions as did those of the Antwerp quadrangle, but probably the Black River Moraine owes its greater relief in part to a bedrock core.

Kame Moraines

One of the largest and most massive kame moraines mapped within the area uncovered by calving retreat lies in the southeastern part of this quadrangle. This moraine seems to have been high enough to stand above the level of Gilbert Gulf, but the surface was nevertheless wave-washed during earlier lake stages. Since the bedrock of this area is limestone, the gravel composing the kames contains a high percentage of carbonate rocks and, in addition, moderate amounts of igneous materials and a small amount of quartzite. The shale content is very low.

This large kamic deposit is designated the Black River kame moraine in this report because it is located on the outskirts of the village of Black River. Where the deposit skirts the Black River to the west of the village, a high bank of gravel has been exposed in the bend of the river. From the river, the kame deposit extends northward for a distance of about 1½ miles to the vicinity of Five Corners, where it is cut by West Creek. The creek apparently dissects the moraine, because a kame with similar material and characteristics continues north of the creek in a northeasterly direction. The surface of the kame moraine has presumably been subjected to much wave action, inasmuch as the summits rise to the 600 foot contour, which is the level most affected by lake waves.

A kame deposit that is probably more important geologically than economically lies mostly in the extreme northwestern part of the Theresa sheet, and extends into the southwest corner of the Alexandria Bay quadrangle. It is the Lafargeville kame moraine. The northern limits of this moraine are about ½ mile southwest of Omar (Alexandria Bay quadrangle), and from this locality it trends southward into the Theresa quadrangle for a distance of 3 miles, and then it swings southeastward for another 2 miles. The ridge is narrow, and rises from 10 to 100 feet above its surroundings. Gravel pits located in the higher parts of the north-south trending section of the moraine reveal lacustrine varved sediments under the frontal gravel, at depths of 6 to 20 feet. This sequence of gravel, interbedded with lake clay, supports the theory of a calving retreat of the ice-front. The presence of bedrock exposures in areas of the kame suggests that the gravel is quite shallow.

Clayton and Cape Vincent Quadrangles

The Clayton and Cape Vincent quadrangles lie to the west of the Theresa sheet. Because only a small area of the Cape Vincent quadrangle lies in New York State, jutting out into Lake Ontario, it is included with the Clayton quadrangle. Both of these quadrangles lie wholly within the area of tableland topography, and have very few surface deposits of importance in interpretation of the glacial geology. Much bedrock, mostly Ordovician limestone, is exposed and even the lake sediments are of small bulk and quite thin.

Beach Gravel

Beach gravel deposits in this area are quite thin and of small extent. The most significant deposits of this type, mapped in the western part of the lowland, occur on the slopes of Luther and Doanes Hills east of Guffin Bay in the southern part of the Clayton quadrangle. As stated above, these deposits are hardly enough to mask completely the underlying bedrock, and it would have been just as correct to map these hills as bedrock, but the beach gravel was more significant in the present study.

On the western slope of Luther Hill, the gravel is concentrated into beach ridges at various levels from the top of the hill at 388 feet to the level of Lake Ontario at 246 feet. This sequence of ridges down the slope of the hill seems to show a gradual emergence above the waters of Gilbert Gulf as the land rose.

Kame Moraines

Two areas of kame moraines in the Sawmill Bay area are noted in this report because they contain a moderate supply of gravel near the St. Lawrence River. The first of these deposits is located immediately southwest of Sawmill Bay, and follows the St. Lawrence River for a distance of about 2 miles. The southeastern side of the moraine has a very sandy surface, probably due to wave action, and the northwestern slope is mostly covered with lake sediments, but gravel pits along the crest of the structure reveal good, clean, kame gravel with a predominantly coarse texture. Along the shore of Sand Bay, 1 mile southeast of Sawmill Bay, 20 to 40 feet of pebbly sand is exposed in the bank of the river. It is believed that the pebbly sand was carried from the kame proper by wave action during a lower stage of Gilbert Gulf.

The northeastern margin of the second kame moraine in the Sawmill Bay area borders the St. Lawrence River 1 mile southwest of Bartlett Point, and trends in a southwest direction for a distance of 3 miles. The major part of this moraine follows a bedrock escarpment, which it covers, and therefore the gravel is not very deep. The extreme southwestern end of the moraine, including the high area of the Hogback triangulation point (454), apparently does not have a bedrock core and therefore contains a large amount of gravel.

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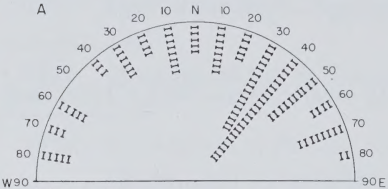
Appendix I

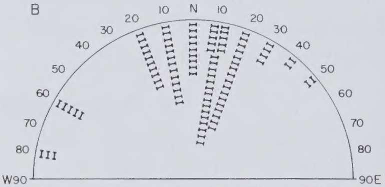
Each of the following till fabric diagrams depicts the distribution of long axes of approximately 100 flattish stones, measured in near horizontal position in undisturbed till. The diagrams are listed in the order that they are mentioned in the text.

A



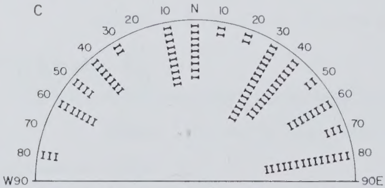
Malone Quadrangle
Webster Avenue in Malone, red-brown till

B



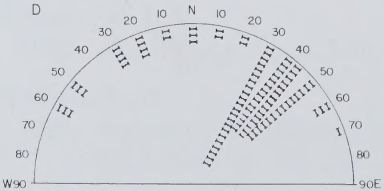
Malone Quadrangle 2.5 miles northeast of Malone,
at Trout River Bridge borrow pit, red-brown till below buff till

C



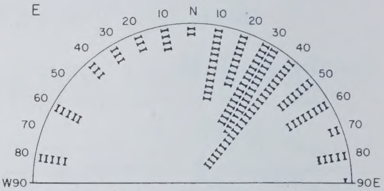
Malone Quadrangle 2.5 miles northeast of Malone,
0.5 mile east of Trout River Bridge, red-brown till

D



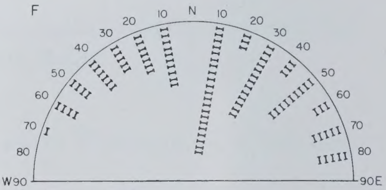
Canton Quadrangle
2.5 miles southeast of Canton, red-brown till

E



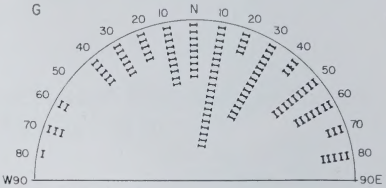
Potsdam Quadrangle
3.5 miles northeast of Parrishville, red-brown calcareous till

F



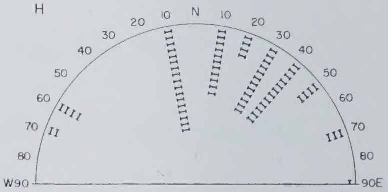
Russell Quadrangle
1 mile southeast of Hermon, red-brown till

G



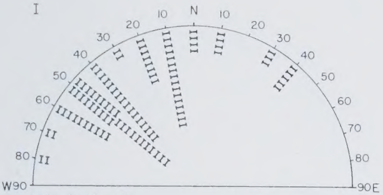
Russell Quadrangle
1.3 miles southeast of Hermon, red-brown till

H



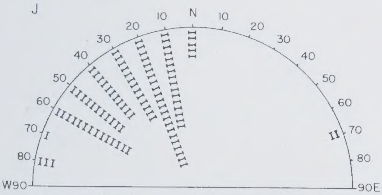
Russell Quadrangle
Mooers Corners, red-brown till

I



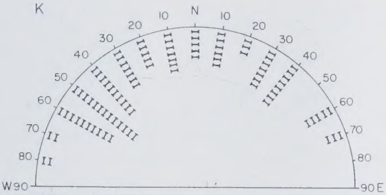
Moira Quadrangle
2 miles southwest of Moira, buff till

J



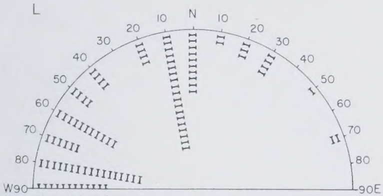
Canton Quadrangle
Campus of St. Lawrence College, buff till

K



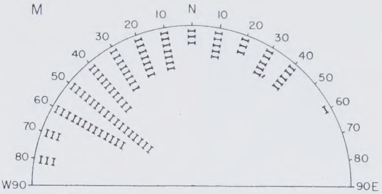
Massena Quadrangle
North end of Massena Canal, gray till

L



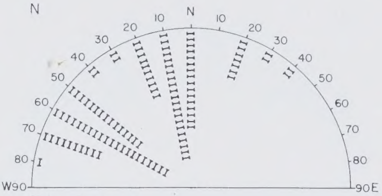
Canton Quadrangle
2 miles west of Potsdam, gray-buff till

M



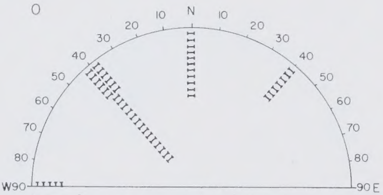
Moira Quadrangle
1 mile west of Bombay, gray-buff till

N



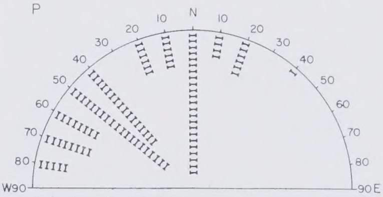
Malone Quadrangle
3 miles north-northeast of Bangor Station, blue-gray till

O



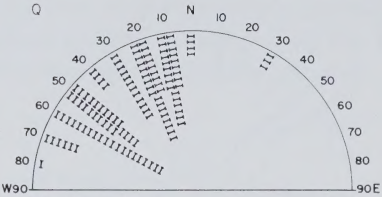
Malone Quadrangle 2.5 miles northeast of Malone, 0.25 mile northwest of Trout River Bridge, blue-gray till
(Stones recorded on quadrants to ascertain only the general direction of ice movement)

P



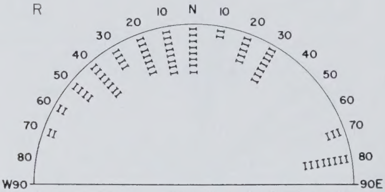
Ogdensburg Quadrangle
East end of Mount Lona, buff till

Q



Nicholville Quadrangle
Dickinson Center, buff till below deltaic pebbly sand

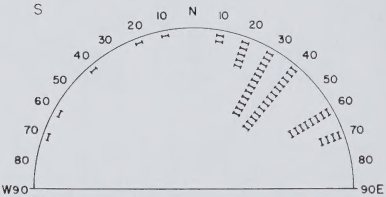
R



Moira Quadrangle Brasher Iron Works, buff till?

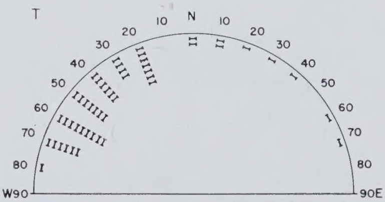
Note: The stones here are mostly irregular angular pieces of limestone with about equidimensional axes, and the orientation means very little.

S



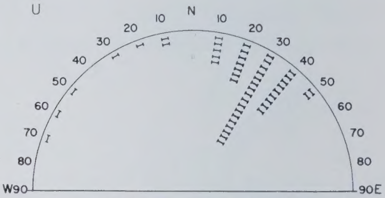
Chateaugay Quadrangle 1 mile northeast of Earlville, west of Hinchin Brook, red-brown till

T



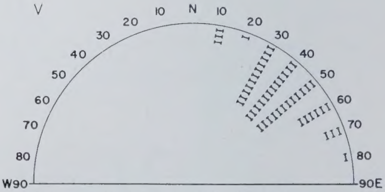
Chateaugay Quadrangle 1.25 miles north of Burke Center, south slope of gentle ridge north of Alder Creek, roadcut, buff till

U



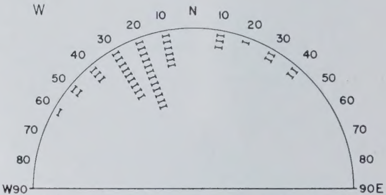
Chateaugay Quadrangle .75 mile north of Burke Center, south side of Alder Brook, red-brown till

V



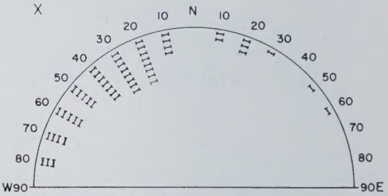
Chateaugay Quadrangle 2.75 miles north-northwest of Burke Center, south side of Little Trout River, red-brown till

W



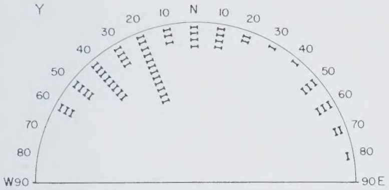
Chateaugay Quadrangle 2.75 miles north-northwest of Burke Center, on north valley wall of Little Trout River, buff till

X



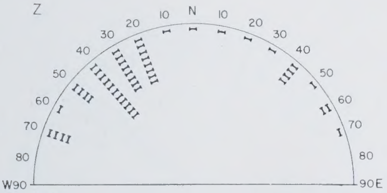
Gouverneur Quadrangle
Kents Corners, 10 feet down in dug well, buff till

Y



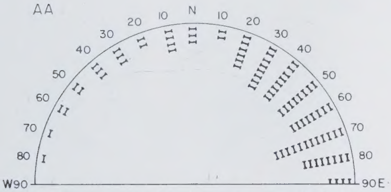
Gouverneur Quadrangle
1.5 miles southwest of Edwards, steep roadcut, buff till

Z



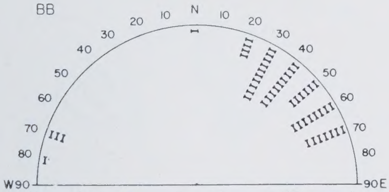
Quebec
1.15 miles west of Covey Hill village, roadside exposure

AA



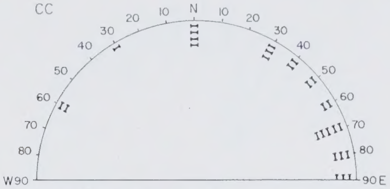
Quebec 1.50 miles south of Franklin Center

BB



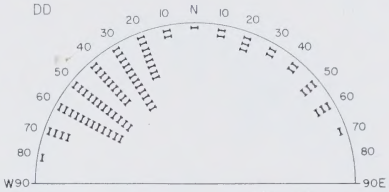
Mooers Quadrangle 1 mile southwest of Mooers Forks

CC



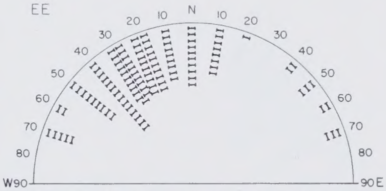
Mooers Quadrangle
3 miles east of Mooers, small roadside exposure

DD



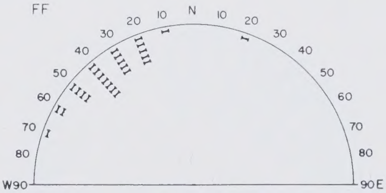
Quebec Covey Hill, east slope,
foundation excavation, Mr. White's house

EE



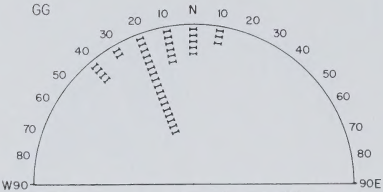
Mooers Quadrangle 1.5 miles north of Mooers

FF



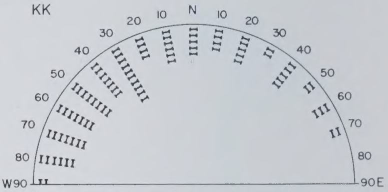
Quebec 0.5 mile southeast of Franklin Center,
roadside exposure, crest of Fort Covington Moraine

GG



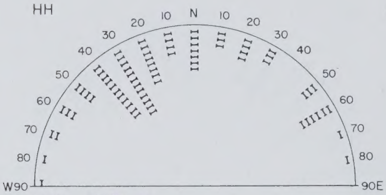
Quebec 4.2 miles east of Franklin Center, roadside exposure, altitude 720'

KK



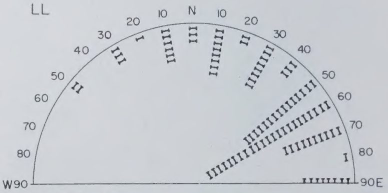
Rouses Point Quadrangle
Railroad underpass in Rouses Point

HH



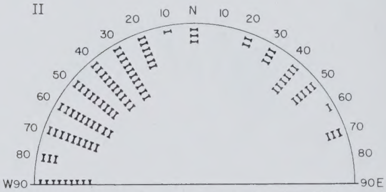
Mooers Quadrangle
2 miles north-northeast of Cannóns Corners

LL



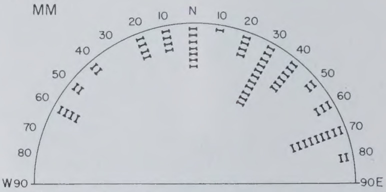
Malone Quadrangle
Webster Avenue, Malone, red-brown till

II



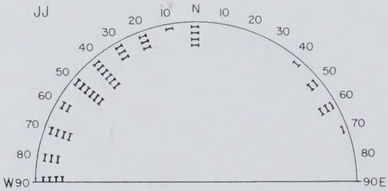
Quebec 4.5 miles east of Covey Hill village

MM



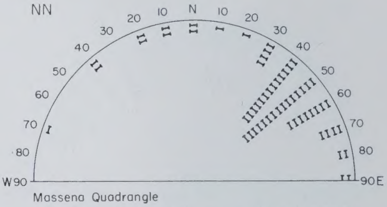
Massena Quadrangle
Grass River Lock, lower till, 10 feet above its base

JJ



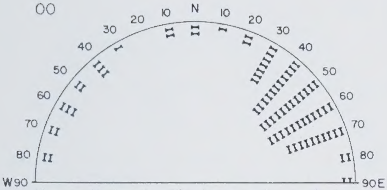
Rouses Point Quadrangle
2 miles southwest of Champlain

NN



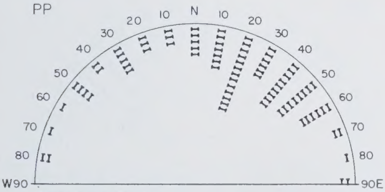
Massena Quadrangle
Eisenhower Lock, basal till on rock striated S 60° W

OO



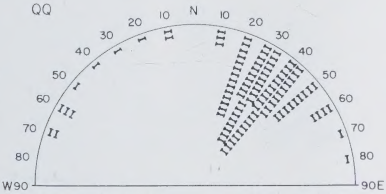
Massena Quadrangle Eisenhower Lock, north side, below overlook, middle till, 15 feet above its base

PP



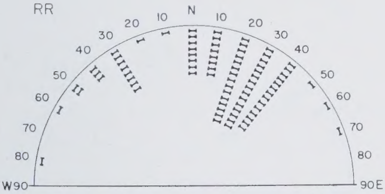
Massena Quadrangle
South Forebay Dike barrow pit, Barnhart Island

QQ



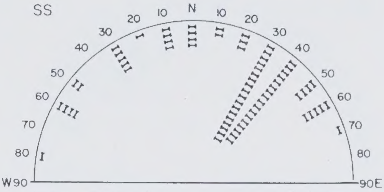
Massena Quadrangle Long Sault Dam, south abutment, basal till below the clay zone

RR



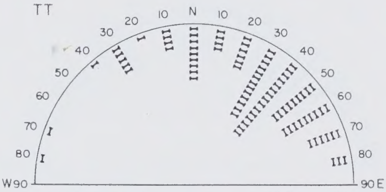
Massena Quadrangle Long Sault Dam, south abutment, till above the clay zone

SS



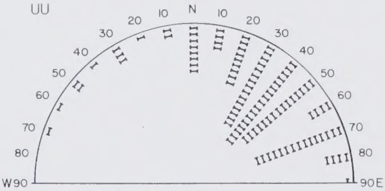
Massena Quadrangle Long Sault Dam, south abutment, buff till 10 feet below top of excavation

TT



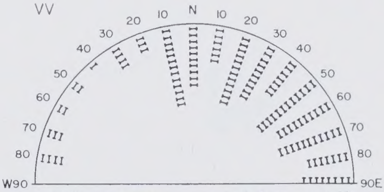
Massena Quadrangle Cut "F", lower till, 15 feet above its base on bedrock, striated S 60° W

UU



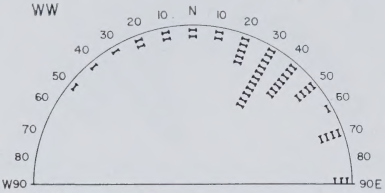
Massena Quadrangle
Power Canal Intake, west side, middle till

VV



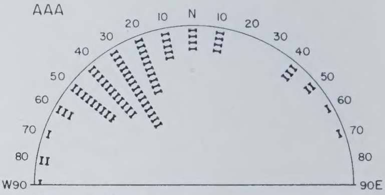
Red Mills Quadrangle Iroquois Dam, east side, lower till on bedrock, striated N 40° E

WW



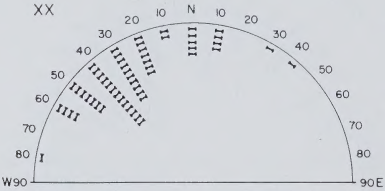
Red Mills Quadrangle
Iroquois Dam, south side of excavation, lower till

AAA



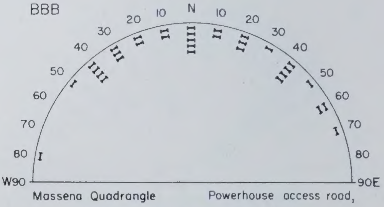
Massena Quadrangle
electric switching yard, Barnhart Island Powerhouse

XX



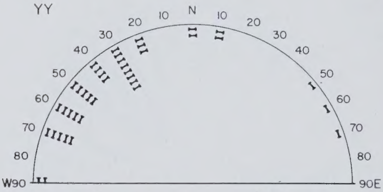
Massena Quadrangle Grass River Lock,
upper till, 10 feet above its bottom

BBB



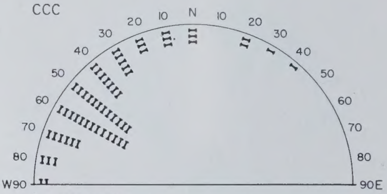
Massena Quadrangle Powerhouse access road,
west side, slumped or "reworked" till

YY



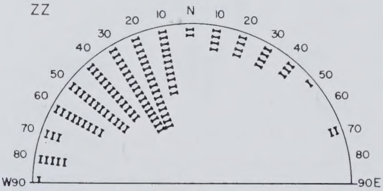
Massena Quadrangle Eisenhower Lock,
upper till, unoxidized 10 feet above its base

CCC



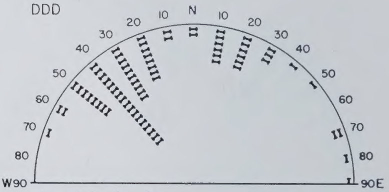
Massena Quadrangle
Cut "F", upper till, unoxidized, 26 feet below its top

ZZ



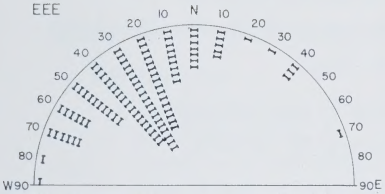
Massena Quadrangle Eisenhower Lock,
east end, till below marine clay

DDD



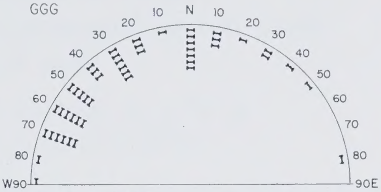
Massena Quadrangle
Cut "F", upper till, oxidized, 8 feet below its top

EEE



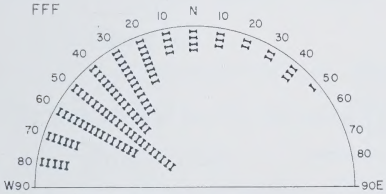
Massena Quadrangle Power Canal intake, southwest of bridge, upper till, 30 feet above its base

GGG



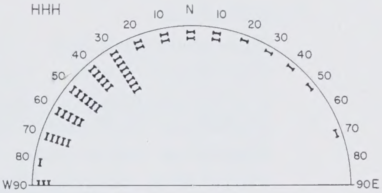
Massena Quadrangle
Long Sault Dike cutoff trench at middle road

FFF



Red Mills Quadrangle
Iroquois Dam, upper till, east side of excavation

HHH



Massena Quadrangle
Knob No. I, South Sault Channel

Appendix II

Report on Fossils from Localities Along the St. Lawrence Seaway and Power Project, New York State

by F. J. E. Wagner, (1956), *Paleontologist*
of the Geological Survey of Canada

1. Grass River Lock, North Pintle Line

Station 100 feet S. Elevation, top of test pit, 168.3 feet

Foraminifera
- *?Laryngosigma* spp. (2)
- *Elphidium clavatum* Cushman
- *Elphidium frigidum* Cushman
- *Elphidium orbiculare* (Brady)
- *Elphidium subarcticum* Cushman
- *Cassidulina norcrossi* Cushman

Porifera
- *Tethea logani* Dawson—a few isolated spicules

Pelecypods
- *Nucula* sp.
- *Yoldia arctica* (Gray)
- *Macoma calcarea* (Gmelin)
- *Hiatella arctica* (Linne)

Ophiuroidea
- *Ophioglypha* sp.

Ostracoda
- *Cyprideis sorbyana* (Jones)
- ? *Xestoleberis* sp.
- 1 species ostracod unident.

Station 200 feet S. Elevation, top of test pit, 162.9 feet

Foraminifera
- *Elphidium clavatum* Cushman
- *Elphidium orbiculare* (Brady)
- *Cassidulina islandica* Nrvang
- *Cassidulina norcrossi* Cushman

Bryozoa
- an unidentifiable specimen

Ophiuroidea
    single ophiuroid plate

Pelecypoda
    Yoldia arctica (Gray)

Station 300 feet S. Elevation, top of test pit, 154.1 feet

Foraminifera
    Quinqueloculina seminula (Linne)
    Quinqueloculina sp.
    Cassidulina islandica Nrvang
    Cassidulina norcrossi Cushman

Pelecypoda
    Yoldia arctica (Gray)

Ostracoda
    Cytheropteron spp. (2)

Station 400 feet S. Elevation, top of test pit, 144.6 feet

Foraminifera
    Quinqueloculina seminula (Linne)
    Cassidulina islandica Nrvang
    Cassidulina norcrossi Cushman

Pelecypoda
    Yoldia arctica (Gray)

Ostracoda
    1 species indet.

Station 500 feet S. Elevation, top of test pit, 133.4 feet

Foraminifera
    Cassidulina islandica Nrvang

Pelecypoda
    Yoldia arctica (Gray)

2. Grass River Lock, South Pintle Line
Station 100 feet N. Elevation 166 feet
Test pit, 1 foot below ground level

Foraminifera
    ? *Laryngosigma* sp.
    Elphidium clavatum Cushman
    Elphidium orbiculare (Brady)
    Elphidium sp.
    Cassidulina islandica Nrvang

Porifera
    Tethea logani Dawson—a few isolated spicules

Pelecypoda
- *Yoldia arctica* (Gray)

Ostracoda
- *Cytheropteron* sp.
- 1 species indet.

Collection from surface of ground

Foraminifera
- ? *Quinqueloculina* sp.
- *Elphidium clavatum* Cushman
- *Elphidium orbiculare* (Brady)
- *Cassidulina islandica* Nrvang
- *Cassidulina norcrossi* Cushman
- 2 species indet.

Porifera
- *Tethes logani* Dawson—isolated spicules

Ophiuroidea
- Spine from ophiuroid arm

Pelecypoda
- *Yoldia arctica* (Gray)
- *Macoma calcarea* (Gmelin)
- *Hiatella arctica* (Linne)

Ostracoda
- *Cyprideis sorbyana* (Jones)
- *Cytheridea punctillata* Brady ?
- *Cytheropteron* sp.

3. Gravel pit at Raquette River village

Foraminifera
- *Elphidium bartletti* Cushman
- *Elphidium* cf. *E. incertum* (Williamson)
- *Cassidulina norcrossi* Cushman

Pelecypoda
- *Mytilus edulis* Linne
- *Macoma balthica* (Linne)
- *Hiatella arctica* (Linne)

Ostracoda
- ? *Xestoleberis* sp.
- 1 species indet.

4. East end of Eisenhower lock; specimens from the marine clays

Foraminifera
- ? *Fissurina* sp.
- *Globulina gracilis* Cushman and Ozawa

Pseudopolymorphina novangliae (Cushman)
Nonion cf. *N. pauciloculum albiumbilicatum* Weiss
Elphidium bartletti Cushman
Elphidium orbiculare (Brady)
Cassidulina islandica Nrvang
Cassidulina norcrossi Cushman

Porifera
Tethea logani Dawson

Pelecypoda
Yoldia arctica (Gray)
Thyssira gouldii (Philippi)
Mytilus edulis Linne
Macoma balthica (Linne)
Macoma calcarea (Gmelin)
Hiatella arctica (Linne)

Ostracoda
Cyprideis sorbyana (Jones)
Cytheropteron inflatum Brady

Cirripedia
Balanus crenatus Bruguiers

5. Premo pit, 1½ miles west of Massena

Foraminifera
Elphidium bartletti Cushman

Pelecypoda
Macoma balthica (Linne)
Hiatella arctica (Linne)

Remarks

Assemblages from the north pintle line station 100 feet S. and south pintle line station 100 feet N. are comparable, and are indicative of relatively shallow (18-25 fathoms) marine conditions. Faunas from the north pintle line area suggest that similar depths prevailed during the time of deposition of the marine part of the section. In the early stages, the water was presumably less saline, and only as truly marine conditions were approached did the more varied assemblages of the upper part of the section move into the area. The species from the lower elevations can tolerate a certain amount of brackishness of the water. Although they are also present higher in the section, there are also species that are less tolerant of freshening of the water.

Raquette River pit: The abundance of *Mytilus edulis* and *Macoma balthica* show the gravel deposit in the Raquette River pit to have been formed in water that was probably less than 1 fathom deep.

In the Eisenhower lock area, one bed near the top of the section was deposited in water only a few feet deep. *Mytilus edulis* is extremely abundant in this bed, and does not occur lower in the section. For the rest of the section, the depth during deposition was probably between 20 and 25 fathoms.

The assemblage from the Premo pit west of Massena is too small to be diagnostic.

Frances J. E. Wagner, 1956

At the Richard's Landing Cutoff trench and at the Red Mills cofferdam excavation, several feet of fossiliferous fresh-water silts lie on the fossiliferous marine clay. Dr. Horace Richards, Philadelphia Academy of Science, identified the following forms from silt below 2 feet of muck at the Red Mills cofferdam, collected and submitted by John Harris.

Valvata tricarinata Say
Stagnicola palustris (Muller) the most abundant
Menetus deflectus Say
Amnicola limosa Say
Helisoma anceps Menke
Goniobasis livescens Menke
Physa gyrina Say
Physa sp.
Pisidium sp.

All are living in the same general area today, and are fresh-water forms.

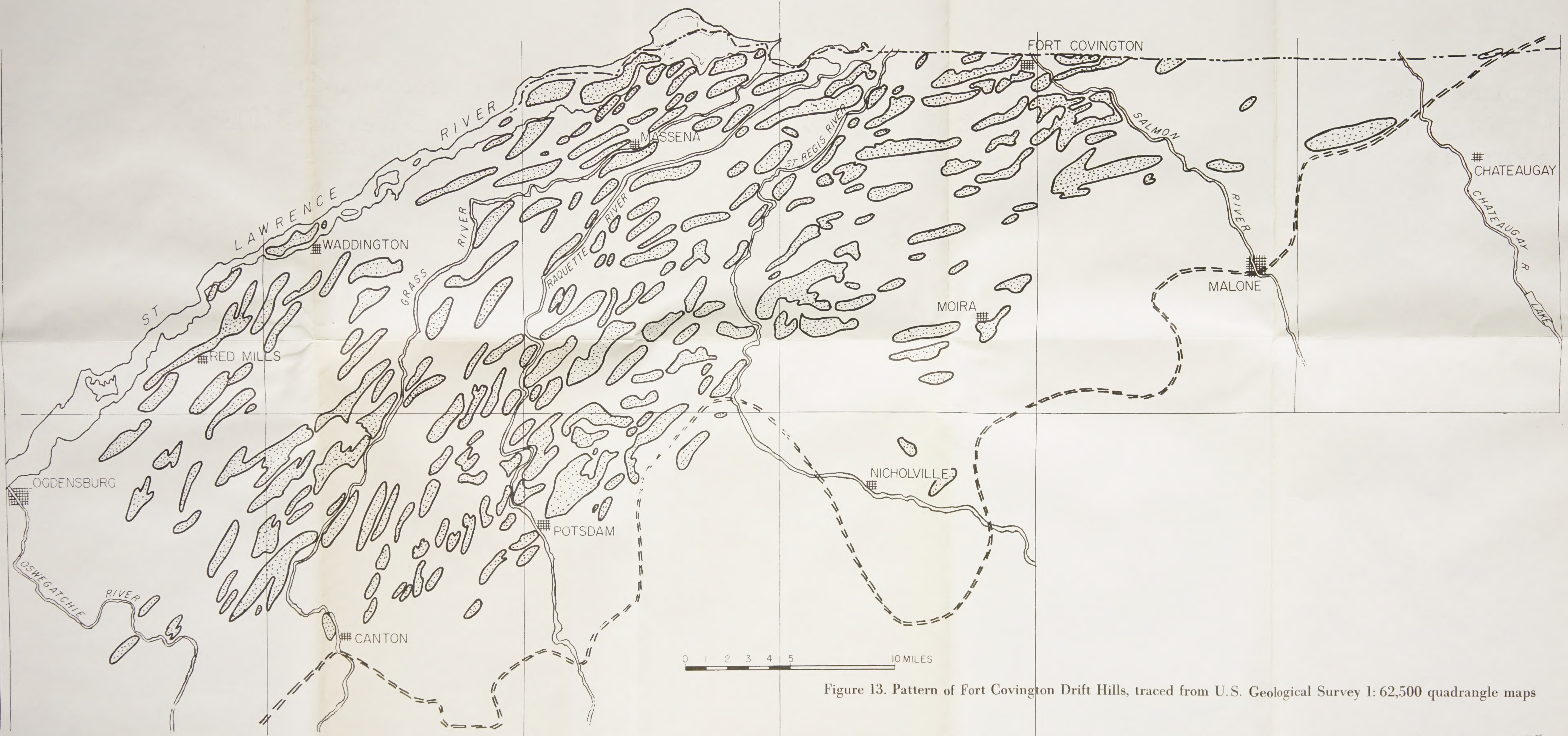

ST. LAWRENCE RIVER
FORT COVINGTON
MASSENA
SALMON RIVER
CHATEAUGAY
CHATEAUGAY R.
LAKE
ST REGIS RIVER
RAQUETTE RIVER
GRASS RIVER
WADDINGTON
RED MILLS
MALONE
MOIRA
OGDENSBURG
NICHOLVILLE
POTSDAM
OSWEGATCHIE RIVER
CANTON
0 1 2 3 4 5 10 MILES

Figure 13. Pattern of Fort Covington Drift Hills, traced from U.S. Geological Survey 1: 62,500 quadrangle maps

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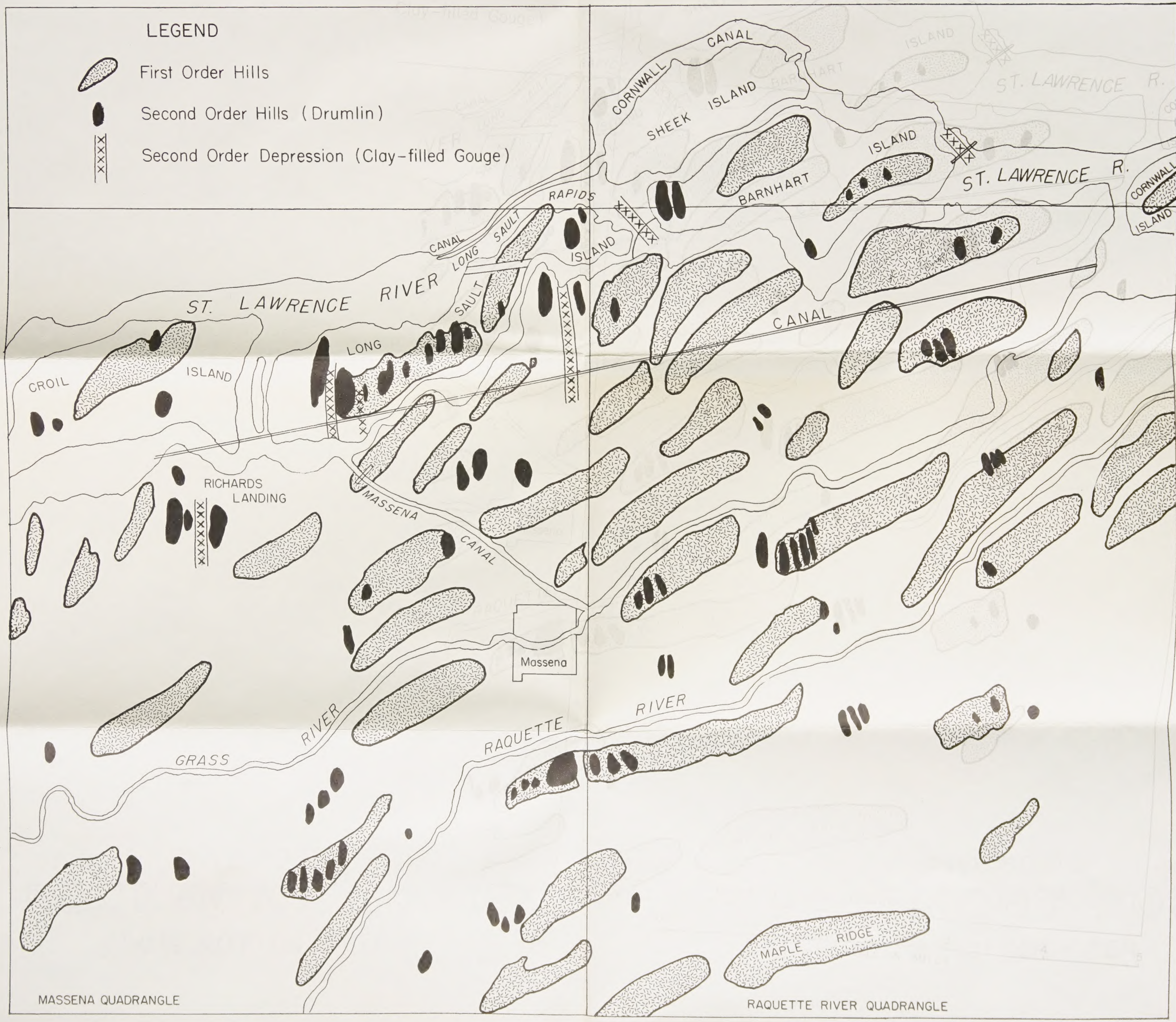
LEGEND
First Order Hills
Second Order Hills (Drumlin)
Second Order Depression (Clay-filled Gouge)
CORNWALL CANAL
SHEEK ISLAND
BARNHART ISLAND
ST. LAWRENCE R.
CORNWALL ISLAND
RAPIDS
LONG SAULT ISLAND
CANAL
LONG SAULT
ST. LAWRENCE RIVER
CANAL
CROIL ISLAND
LONG
RICHARDS LANDING
MASSENA CANAL
Massena
GRASS RIVER
RAQUETTE RIVER
MAPLE RIDGE
MASSENA QUADRANGLE
RAQUETTE RIVER QUADRANGLE
0
1
2
3
4
5
SCALE IN MILES

Figure 16. Topography in the vicinity of Massena

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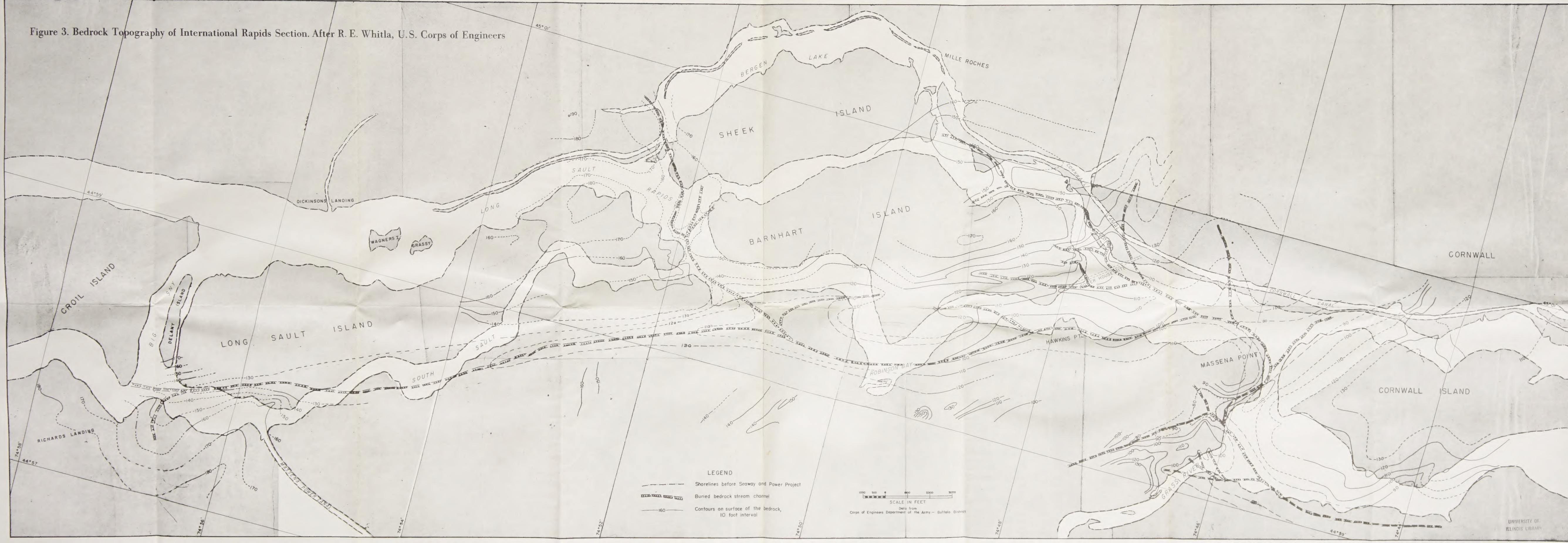
Figure 3. Bedrock Topography of International Rapids Section. After R. E. Whitla, U.S. Corps of Engineers


45°01'
BERGEN LAKE
MILLE ROCHES
SHEEK ISLAND
BARNHART ISLAND
LONG SAULT RAPIDS
DICKINSONS LANDING
WAGNERS I.
GRASSY
CROIL ISLAND
BIG SNY
DELANY ISLAND
LONG SAULT ISLAND
SOUTH SAULT
RICHARDS LANDING
MASSENA POWER CANAL
CORNWALL CANAL
POWER HOUSE SITE
HAWKINS PT.
ROBINSON BAY
MASSENA POINT
CORNWALL
CORNWALL ISLAND
GRASS RIVER
44°59'
44°58'
44°57'
74°56'
74°54'
74°52'
74°50'
74°48'
74°46'
74°44'
LEGEND
Shorelines before Seaway and Power Project
Buried bedrock stream channel
160
Contours on surface of the bedrock, 10 foot interval
1000 500 0 1000 2000 3000
SCALE IN FEET
Data from
Corps of Engineers Department of the Army — Buffalo District

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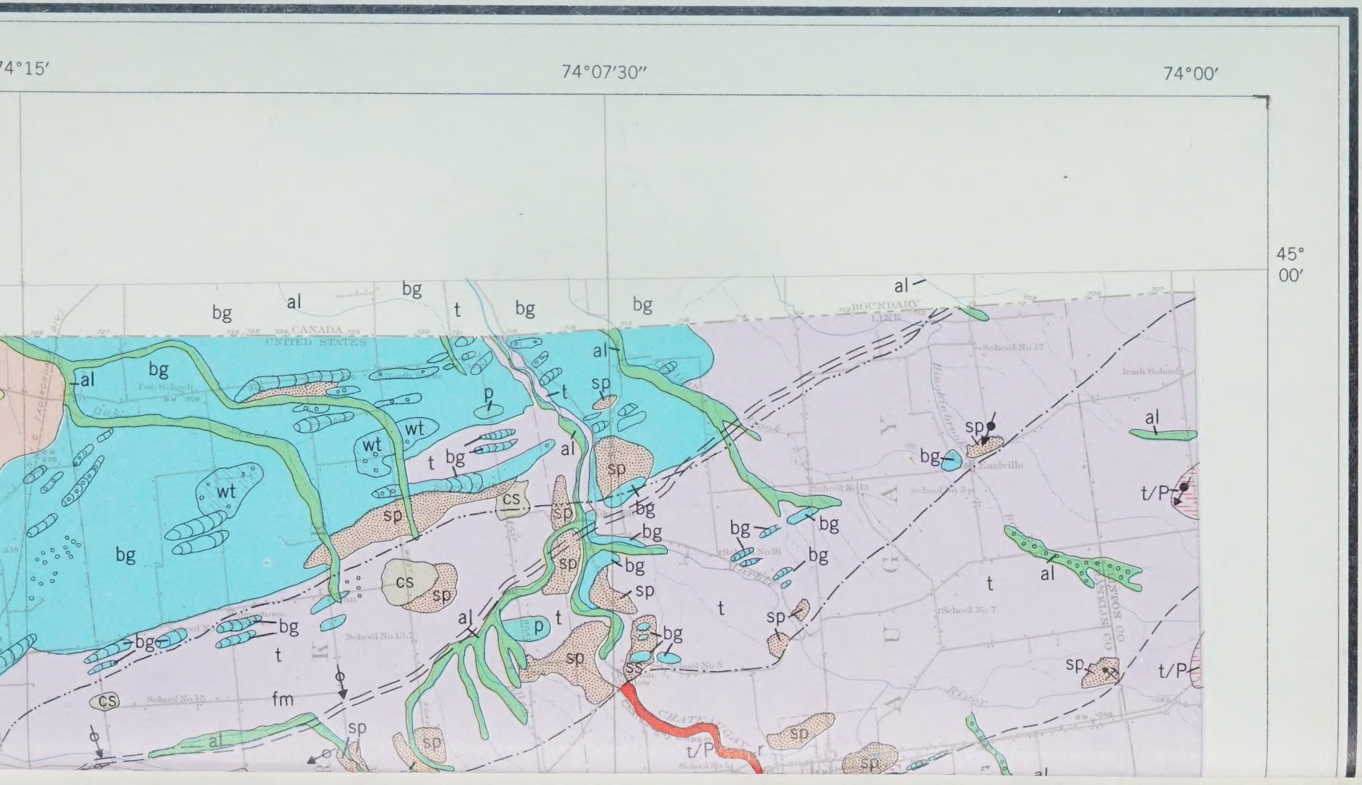
GEOLOGICAL SURVEY
John G. Broughton, State Geologist


74°15′
74°07′30″
74°00′
45°
00′
BOUNDARY LINE
CANADA
UNITED STATES
School No 17
Irish School
Earlville
School No 3
School No 13
School No 16
School No 5
School No 7
School No 15
Fee School
North Burke
CLINTON CO
FRANKLIN CO
Hinchinbrook
Marble
Oak
CHATEAUGAY
River
ADIRONDACK DIV
al
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sp
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ss
fm
t/P
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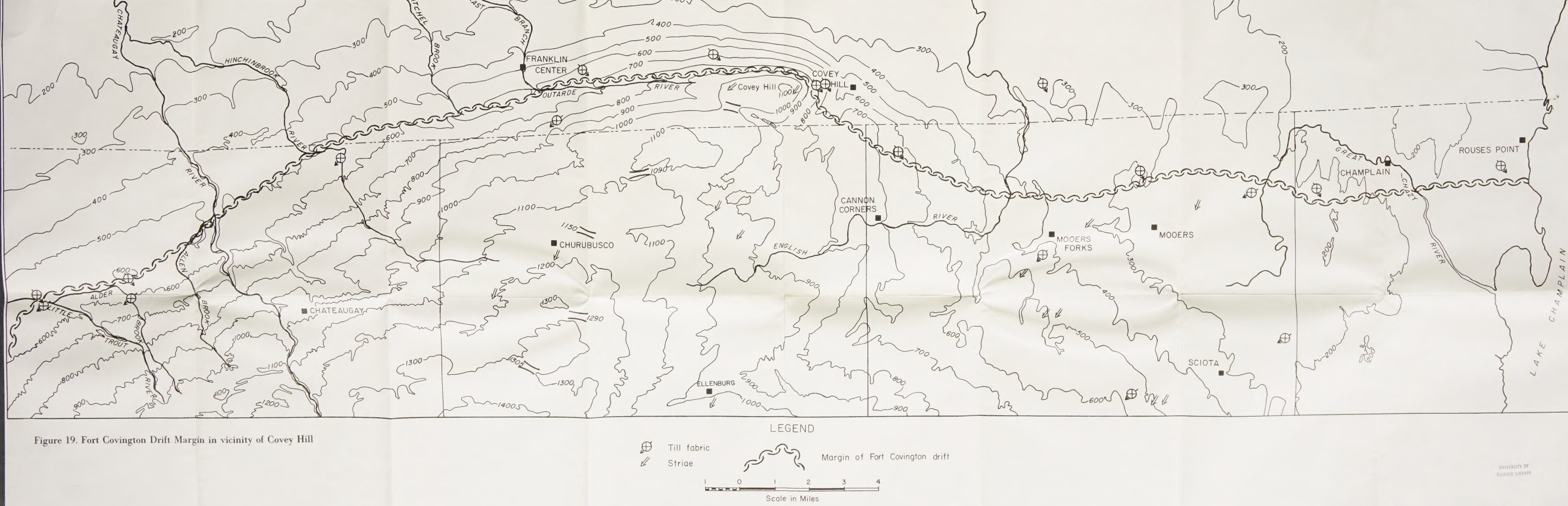
CHATEAUGAY
HINCHINBROOK
MITCHEL BROOK
EAST BRANCH
FRANKLIN CENTER
OUTARDE
RIVER
Covey Hill
COVEY HILL
CANNON CORNERS
ENGLISH RIVER
CHURUBUSCO
CHATEAUGAY
ALLEN BROOK
ALDER
LITTLE TROUT RIVER
TROUT BROOK
ELLENBURG
MOOERS FORKS
MOOERS
SCIOTA
GREAT CHAZY RIVER
CHAMPLAIN
ROUSES POINT
LAKE CHAMPLAIN
200
300
400
500
600
700
800
900
1000
1090
1100
1150
1200
1290
1300
1305
1400
LEGEND
Till fabric
Striae
Margin of Fort Covington drift
1 0 1 2 3 4
Scale in Miles

Figure 19. Fort Covington Drift Margin in vicinity of Covey Hill

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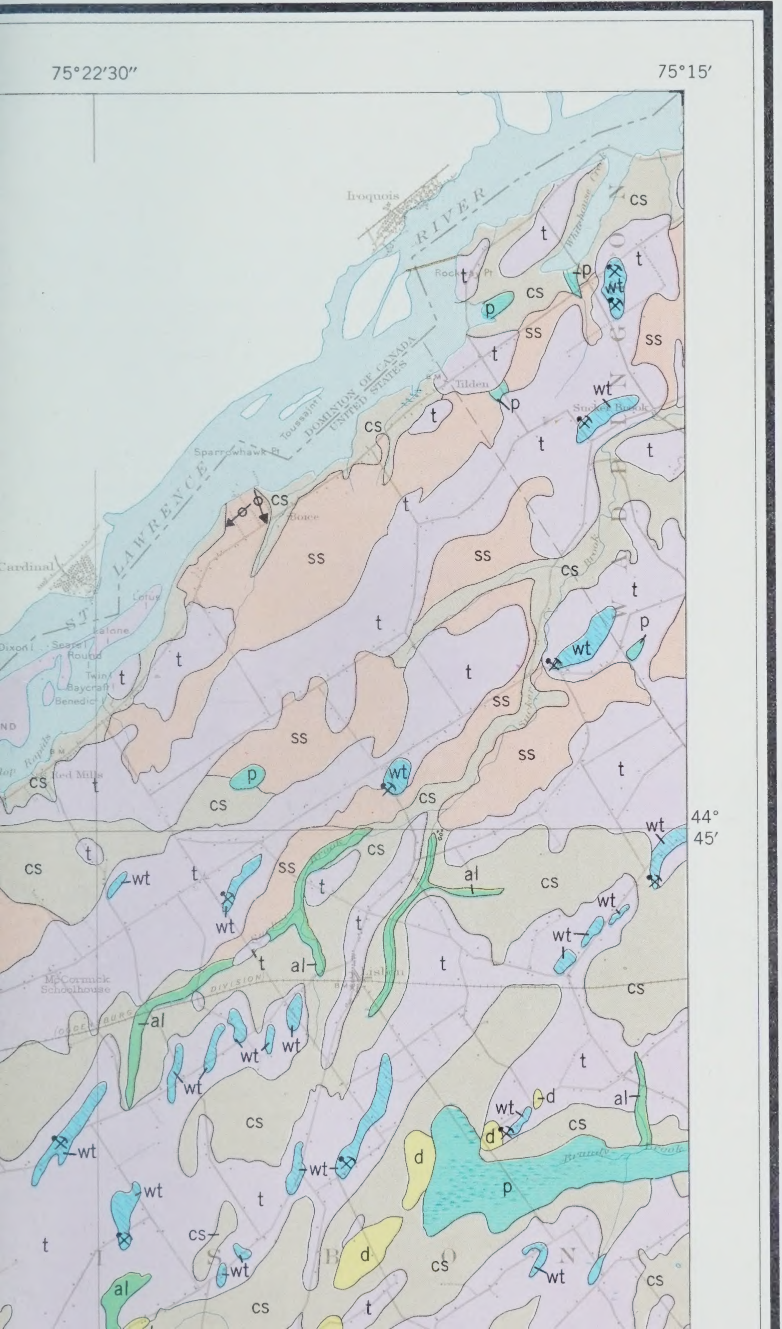
75°22'30"
75°15'
44°
45'
ST. LAWRENCE RIVER
DOMINION OF CANADA
UNITED STATES
Iroquois
Rockaway Pt
Tilden
Toussaint
Sparrowhawk Pt
Boice
Cardinal
Lotus
Galone
Dixon I
Seare I
Round
Twin I
Baycraft I
Benedict I
Rapids
Red Mills
McCormick Schoolhouse
Lisbon
Whitehouse Creek
Sucker Brook
Brandy Brook
Brook
OGDENSBURG DIVISION
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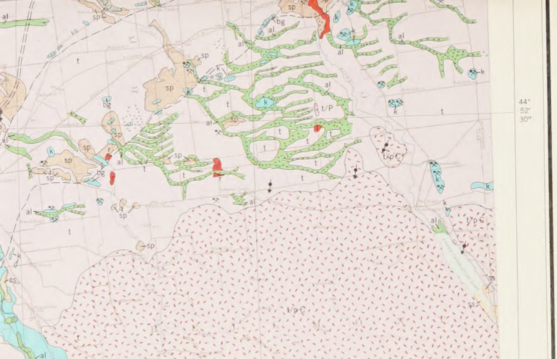
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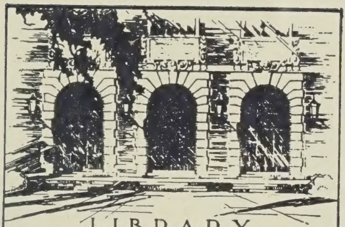

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